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INTRODUCTION.

During the summer of 1913 the Secretary of Agriculture established a board to reorganize the system of publications of the Department of Agriculture. In accordance with the proceedings of the board and the suggestions from representatives of the Weather Bureau, the "Bulletin of the Mount Weather Observatory" ceased to be published with the completion of its volume 6. Any subsequent contributions from the members of the research staff that would have been proper for that Bulletin will be incorporated in the Monthly Weather Review. The climatological service of the Weather Bureau will be maintained in all its essential features, but its publications, so far as they relate to purely local conditions, will be incorporated in the monthly reports for the respective States, Territories, and colonies.

Beginning with January, 1914, the material for the Monthly Weather Review will be prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 6.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto.

In general, appropriate officials will prepare the six sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions that have during recent years been prepared by the 12 respective "district editors" will be omitted from the Monthly Weather Review, but will in future be collected and published by States at selected section centers.

The data needed in section 6 can only be collected and prepared several weeks after the close of the month whose name appears on the title page; hence the Review as a whole can only issue from the press within about eight weeks from the end of that month.

The Annual Summary of the Review will hereafter appear as an Annual Supplement containing the essential tables heretofore published in the annual Report of the Chief of the Weather Review.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are especially due to the following directors and superintendents:

The Meteorological Service of the Dominion of Canada.
The Central Meteorological and Magnetic Observatory of Mexico.
The Director General of Mexican Telegraphs.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, St. Petersburg.
The Philippine Weather Bureau.
The General Superintendent United States Life-Saving Service.

SECTION I.—AEROLOGY.

THE ERUPTION OF SAKURASHIMA, JANUARY, 1914.

In view of the great interest which violent volcanic explosions have for the modern student of insolation, atmospheric transmissibility, and sky polarization, it seems appropriate for this REVIEW to present briefly the important features of the eruption of Sakurashima so far as they bear upon such problems.

Southern Japan has a great group of volcanoes called Kirishima. Southwestward from that group stretches a volcanic zone along the inner line of the Riukiu arc, and this zone also bears the general name Kirishima. Sakurashima is a volcanic island of this zone, situated in the graben which forms the Bay of Kagoshima, and its volcanoes are the first of those in the zone stretching southwestward from the Kirishima group.

The conical island of Sakurashima, 8½ kilometers from north to south and 11 kilometers from east to west, is built of three volcanic cones, lying so close together along its meridian that from the base they appear as a single cone. From one of the summits the individual cones may be clearly distinguished. The northern volcano is called Mitake or Kita-dake, i. e., Northern Peak; its rim is 1,133 meters above sea level; its crater is 300 meters in diameter and 100 meters deep. The southern volcano is called Minami-dake, or Southern Peak, and has always been active during historic times, giving off a light smoke or steam. Its elliptical crater is 650 by 400 meters, bounded by extraordinarily steep and even perpendicular walls, and the rim stands at an altitude of 1,070 meters above sea level. Between these two lies the third cone, called Nake-dake, or Middle Peak, having a smaller crater that is but 30 meters deep and a correspondingly shallow rim. Other lateral and parasitic cones are also present.

This island of volcanoes is among the most famous of Japan. Historic recorded eruptions go back to 708 A. D., since when at least 20 outbreaks have occurred. Among these the most violent were in 1471–1476 and 1779–1781. The eruption of 1780 was accompanied by a submarine outbreak on the northeast of the island which resulted in the formation of new islands and reefs. During the past 135 years there have been over 10 small outbreaks, and smoke clouds were still ascending from Minami-dake when Prof. Yamasaki's[1] paper was transmitted to the Berlin Geographical Society.

The eruption of January, 1914, was one of the most important lava eruptions of modern times, comparable with its own predecessor of 1779 and that of Asama in 1783. The great eruption of Bandai-san in 1888 was a great steam explosion, and no trace of accompanying lava flows was found. The eruption of Sakurashima of the present year was of the normal lava type, as usually occurring at Vesuvius and Etna. It was immediately preceded by numerous earth shocks on January 10, which greatly increased in number on the 11th. Thus the inhabitants of the island and of Kagoshima had sufficient time to flee to points of safety. Early on the morning of January 12 "smoke" was seen hanging upon the western slopes far below the active crater of Minami-dake. About 10 a. m. there was a tremendous eruption precisely underneath the "smoke," and almost simultaneously came another great eruption on the opposite side of the island. Great masses of steam, darkened by their great load of volcanic ashes and lapilli, rose to great heights. The "smoke" column, made up of thousands of cloud balls, is estimated to have risen to at least 6,000 meters (19,685 feet, or 3.7 miles). Lightning flashes darted in all directions, vertically as well as horizontally and obliquely, within the gray cloud. The heavy concussions and the ash fall greatly changed the landscape. Near the crater the forest trees were stripped of their leaves, branches were bent over, and even strong stems and trunks were broken off. The side of the trees toward the crater suffered complete abrasion of bark and rind, so that only the naked stem remained. In Yokohama the air waves tore up by the roots a well-grown orange tree and carried it up on a hill 60 meters above its former position.

The lofty column of "smoke" spread out in the upper layers of the atmosphere, scattering its ashes far eastward under the influence of the west wind then prevailing. The ash fall not only covered the larger portion of the island of Kiushiu, but also fell upon Shikoku and at various points on Hondo, the principal of the Japanese islands. Early on the morning of January 13, the third day of the eruption, there was a thin fall of ashes at Tokyo, which is about 1,000 kilometers or over 620 miles, from Sakurashima.—[C. A., jr.]

[1] *Yamasaki, N.* Der Ausbruch des Vulkans Sakurashima im Januar, 1914. Ztschr. d. Gesells. f. Erdkunde, Berlin, 1914, No. 4, pp. 295–302, with map.

SOLAR RADIATION INTENSITIES AT MOUNT WEATHER, VA.

HERBERT H. KIMBALL, Professor of Meteorology.

[Dated Mount Weather, Va., Apr. 17, 1914.]

In Table 1 are summarized the solar radiation measurements made at Mount Weather, Va., with a Marvin pyrheliometer, during January, February, and March, 1914. Measurements have been made with the sun at approximately the following zenith distances whenever it was unobscured by clouds: 80.7°, 79.8°, 78.7°, 77.4°, 75.7°, 73.6°, 70.7°, 66.5°, 60.0°, and 58.3°. The corresponding air masses are 6.0, 5.5, 5.0, 4.5, 4.0, 3.5, 3.0, 2.5, 2.0, and 1.5 (1). Eight readings of the pyrheliometer at minute intervals are usually made, and the results are plotted with the logarithms of the measured radiation intensities as ordinates and the air masses as abscissas. Interpolation of radiation intensities to a zenith distance of the sun corresponding to an air mass that is some multiple of 0.5 is then a simple matter. The exact zenith distance of the sun corresponding to the true solar time at which a pyrheliometric reading was made is determined by the aid of Ball's altitude tables (2).

The Marvin pyrheliometer has been compared frequently with Smithsonian silver disk pyrheliometer No. 1, and the latter has been checked from time to time with pyrheliometers in use at the astrophysical observatory

of the Smithsonian Institution. It is therefore believed that the results here given are expressed in units of the Smithsonian revised scale of pyrheliometry (3).

TABLE 1.—*Solar radiation intensities at Mount Weather, Va., expressed in gram-calories per minute per square centimeter of normal surface.*

Date.	Air masses.								
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1914. A. m.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Jan. 6	1.23	1.14	1.05						
9		0.98	0.90	0.83	0.77				
13						0.84	0.77	0.72	0.70
14	1.30	1.22	1.14	1.06	0.99	0.93	0.87		
18	1.25	1.12							
23	0.77	0.62	0.50	0.42	0.35	0.31	0.27		
25			0.98	0.89	0.80				
26	1.08								
29	1.21	1.11	1.03	0.96	0.89	0.80			
Means	1.14	1.03	0.93	0.83	0.76	0.72	0.64	*0.72*	*0.70*
P. m.									
Jan. 6		1.20	1.14	1.03	0.94	0.88	0.83	0.79	0.76
14		1.20	1.14	1.06	0.98	0.92	0.87	0.82	
23	0.93	1.04	0.92	0.86	0.86	0.83			
26	1.16	1.03	0.95	0.87	0.81	0.76	0.71	0.66	0.61
27	1.18								
31		1.21							
Means	1.09	1.14	1.04	0.96	0.90	0.85	0.80	0.76	0.68

Date.	Air masses.									
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
A. m.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Feb. 1		1.23								
2		1.38	1.30	1.21	1.13	1.08	1.00	0.99		
7	1.24	1.13	1.06							
8	1.31	1.22	1.09	0.98	0.88	0.80	0.74	0.60		
9	1.47	1.35	1.25	1.15	1.08	1.02	0.95	0.90	0.85	
12	1.31									
15	1.24	1.21				0.85	0.75	0.69	0.65	
17					1.00	0.94	0.88	0.83	0.78	0.73
21	1.46	1.34	1.22	1.12	1.03	0.95	0.89	0.84	0.79	0.73
24	1.46	1.32								
26	1.42	1.34	1.25	1.13	1.05	0.99	0.94	0.88	0.82	0.77
Means	1.36	1.28	1.20	1.12	1.03	0.95	0.88	0.82	0.78	0.74
P. m.										
Feb. 1		1.29	1.15	1.07	1.01	0.95	0.90	0.85	0.79	0.74
2		1.34	1.25	1.14	1.07	1.02	0.98	0.93	0.87	0.82
7		1.04	0.96	0.87	0.79	0.74		0.62	0.57	0.51
8		1.24	1.13							
9		1.34	1.22	1.13	1.06	0.99	0.92	0.86	0.82	0.80
11		0.97	0.82	0.68	0.60	0.54	0.50	0.46	0.43	0.40
15		1.10	1.02	0.95	0.88	0.81	0.75	0.69	0.66	0.63
16		0.77								
17		1.14	1.05	0.96	0.88	0.81	0.71			
21		1.36	1.28	1.20	1.12	1.05	0.99	0.94	0.89	
24		1.35	1.27	1.20	1.12	1.06	1.00	0.95	0.90	0.85
26	1.40	1.20	1.13			0.97	0.89	0.82	0.76	
Means	*1.40*	1.18	1.12	1.02	0.95	0.89	0.85	0.79	0.74	0.68
A. m.										
Mar. 4	1.25									
10	1.29		1.04	0.94	0.84	0.74				
12	1.44	1.34	1.24	1.15	1.06	0.99				
14		1.13	1.03	0.94	0.86	0.79	0.72	0.67	0.61	0.54
15	1.19	1.00								
18		1.16								
21								0.86		
23				1.01	0.92	0.83	0.76	0.70	0.64	
24	1.25	1.15	1.04	0.95	0.84	0.76	0.68	0.61	0.56	0.52
Means	1.28	1.16	1.09	1.00	0.90	0.82	0.72	0.71	0.60	0.53
P. m.										
Mar. 3	1.28	1.19	1.10	0.99	0.90	0.83	0.76	0.69		
4	1.28	1.09	0.97	0.89	0.80					
7	1.29									
9	1.32									
10	1.28		0.94							
12	1.45	1.34	1.23	1.13	1.05	0.99	0.93	0.87	0.82	0.77
15	1.11	0.99	0.89							
20	1.36	1.19								
24	1.11	0.96	0.83	0.74	0.67	0.60	0.54	0.48	0.43	
Means	1.28	1.13	0.99	0.94	0.86	0.81	0.74	0.68	0.62	*0.77*

Both the extreme and the mean solar radiation intensities for February and March, 1914, are in fair agreement with corresponding intensities for previous years (4). This is also true of the intensities for the first 18 days in January; but on the 23d of the month a hazy period set in that is worthy of special consideration.

The sunrise on January 23 was most unusual. About 45 minutes before sunrise there was a faint reddish glow in the east, and stars could be seen near the zenith, but none were visible near the horizon. Just before sunrise the sky was nearly colorless, and had the appearance of being overcast with alto-stratus clouds. At sunrise the sun was invisible, but shortly afterwards it appeared as a dull red ball through a layer of dense haze. It gradually increased in brightness, but the red color had not entirely disappeared when the sun was 10° above the horizon. Only a few wisps of cirrus clouds were present, the whiteness of the sky being due to the haze, which was principally above the level of Mount Weather, as objects in the valleys 16 miles distant were distinguishable.

From Table 1 it is seen that radiation intensities were very low during the morning of the 23d, and with air mass 2.0 were only 61 per cent of the average for the first part of the month. They were, in fact, nearly as low as as any that were measured during the haze that prevailed in 1912 (5). The atmosphere cleared rapidly during the afternoon of the 23d, and with air mass 2.5 the radiation intensity was 87 per cent of the average for the first part of the month.

Solar-radiation intensities continued about 15 per cent below the average, for air mass 2.0, until the 29th. On this day there was a dense lower haze that obscured all objects at a greater distance than 6 miles. The sky at the zenith was a deep blue, however, and the polarization of skylight, measured at a point 90° from the sun and in the same vertical circle, had increased to 60 per cent. On the 23d it was only 34 per cent, and on intervening days had been about 50 per cent.

In figure 1, curve I is a reproduction of the record of the total radiation received by a Callendar horizontal recording pyrheliometer from the sun and sky on January 23. Curve II is a record of the radiation received from the sky alone. It was obtained by interposing a screen 4 inches in diameter between the sun and the receiving grids of the pyrheliometer, and about 22 inches from the latter. Curves III and IV represent corresponding data for January 29. There were a few clouds late in the afternoon of the 23d, and a thin sheet of cirrus during most of the afternoon of the 29th.

In Table 2 are brought together for easy comparison radiation intensities read from the above curves when the sun was at the zenith distances indicated in the heading. It will be noted that the deficit in the total radiation on the 23d is small as compared with the excess of sky radiation. In other words, considerably more than half the loss in direct solar radiation, due presumably to scattering by the dust particles, was made up by the increased radiation from the sky. This is what we might expect when the sun is so far from the zenith.

In Table 3 are given light intensity measurements made with a Sharpe-Millar photometer on these two days, with the translucent glass plate in the end of the photometer tube horizontal. The illumination from the

sky was obtained by interposing the 4-inch screen above referred to between this plate and the sun, and at a distance of about 2 feet from the former. On the 23d, sky illumination was in excess of solar illumination until after noon, and with the sun below zenith distance 70° a horizontal surface was only slightly illuminated by direct solar radiation. On the 29th with the sun at zenith distance 70.7° solar illumination was nearly twice as great as sky illumination, and over 12 times the corresponding solar illumination on the 23d. Evidently the haze on the 23d nearly extinguished the visible rays in the solar spectrum when the sun was low. In fact, with the sun 10° above the horizon it was impossible to make the usual adjustment of the Marvin pyrheliometer by means of a beam of light through a pinhole falling upon a cross mark on white paper.

TABLE 3.—*Photometric measurements at Mount Weather, Va., of the illumination from the sun and sky on Jan. 23 and 29, 1914.*

Date.	Sun's zenith distance.		
	60.0°	66.5°	70.7°
A. m.	TOTAL ILLUMINATION. (*Foot candles.*)		
Jan. 23	3,450	2,300	1,680
Jan. 29	4,160	2,920	2,280
	SKY ILLUMINATION.		
Jan. 23	2,120	1,820	1,560
Jan. 29	980	900	790
	SOLAR ILLUMINATION.		
Jan. 23	1,330	480	120
Jan. 29	3,180	2,020	1,490

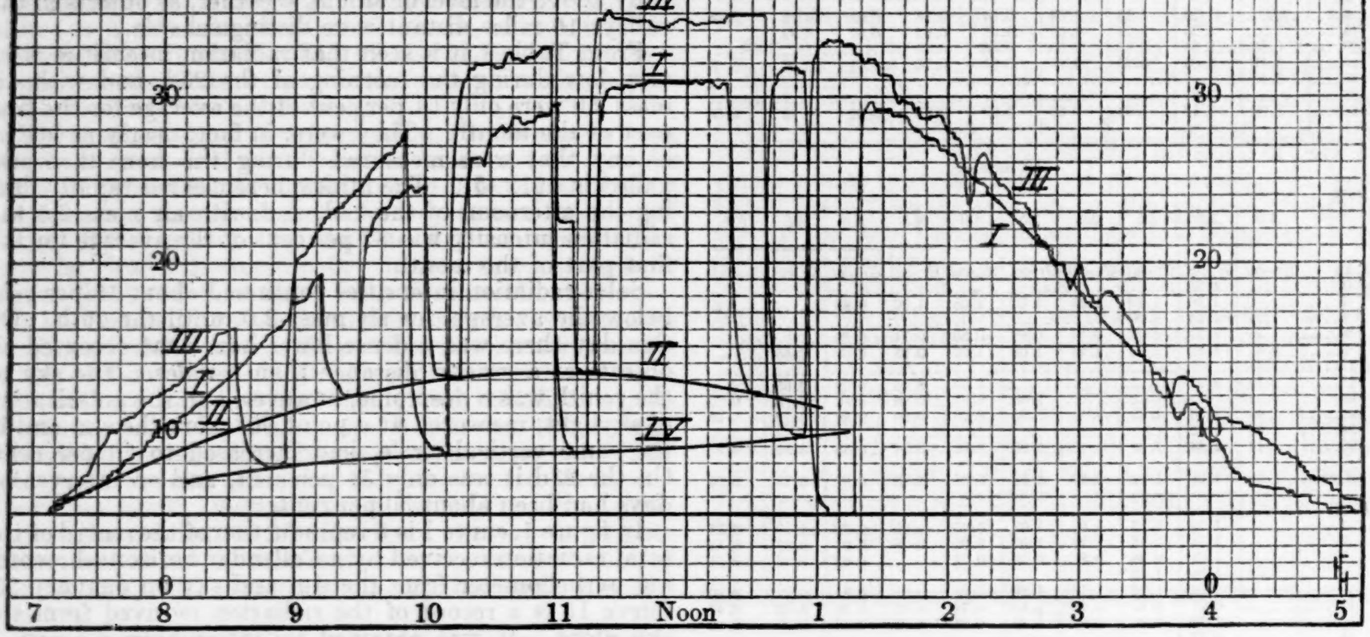

FIG. 1. Curves from a Callendar horizontal recording pyrheliometer at Mount Weather, Va., on Jan. 23 [I and II] and 29 [III and IV], 1914.
I and III, Total radiation received from sun and sky.
II and IV, Radiation from the sky alone, obtained by intermittently screening the grids from the sun.

TABLE 2.—*Comparison of radiation intensities recorded at Mount Weather, Va., by a Callendar horizontal recording pyrheliometer on Jan. 23 and 29, 1914.*

Date.	Sun's zenith distance.					
	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°
A. m.	SOLAR RADIATION. (*Scale divisions.*)					
Jan. 23	16.1	11.4	8.0	5.2	4.3	3.3
Jan. 29	23.9	17.1	12.5	9.8	8.6	7.0
	SKY RADIATION.					
Jan. 23	8.6	7.6	6.6	5.7	5.1	4.7
Jan. 29	3.5	3.1	2.8	2.5	2.3	2.2
Difference	5.1	4.5	3.8	3.2	2.8	2.5
	TOTAL RADIATION.					
Jan. 23	24.7	19.0	14.6	10.9	9.4	8.0
Jan. 29	27.4	20.2	15.3	12.3	10.9	9.2
Difference	2.7	1.2	0.7	1.4	1.5	1.2

Unusually brilliant red twilight colors were observed at Mount Weather on the evening of January 28 and the morning of the 29th. Brilliant sunsets were also observed by Prof. Abbe and others in Washington, D. C., during the latter part of the month.

The haze of January 23, 1914, was similar in its appearance and in its effects upon solar radiation intensities and skylight polarization to the dense haze of June 10–11, 1912, following the eruption of Katmai volcano, in Alaska, on the 6th of the same month. It occurred about 250 hours after the most violent eruptions of Sakurashima volcano, in Japan, on January 12, 1914, or at about the time we might expect dust from that eruption to reach the United States.

So far as I am aware, no unusual optical conditions of the atmosphere were observed elsewhere in the United States at this time; and until observational data from other countries is at hand, such as I understand is being collected by Dr. Chr. Jensen, of Hamburg, it is hardly profitable to speculate as to the cause of the unusual haze observed at Mount Weather during the latter part of January, 1914.

REFERENCES.

(1) Air masses have been computed from the equation

$$m=\frac{\text{atmospheric refraction (in seconds)}}{58.36'' \times \sin Z}$$

(2) Ball, Frederick. Altitude tables. London, 1907.
(3) Abbot, C. G., and Aldrich, L. B. Smithsonian pyrheliometry revised. Smithsonian Misc. Collection. v. 60, No. 18. Washington, 1913.
(4) See Table 2. Bulletin Mount Weather Observatory. Washington, 1912. v. 5, p. 303-311.
(5) Kimball, Herbert H. The dense haze of June 10-11, 1912. Bull. Mount Weather Obsy., Washington, 1912. v. 5, p. 161-165.

STANDARD UNITS IN AEROLOGY.

The views and practice of some American physicists are probably well presented in the following extracts and articles from Profs. T. W. Richards and A. E. Kennelly, both of Harvard University, and which we now publish with their permission.—EDITOR.

1. [*Extract from* "New method for determining compressibility," by Theodore William Richards and Wilfred Newsome Stull. Carnegie Institution of Washington. Publication No. 7. Washington. December, 1903. p. 42-43.]

"It is a matter of great regret that the scientific world has not agreed upon a less arbitrary unit of pressure than the 'atmosphere.' The difficulty is now increased by the frequent technical use of this word to designate the pressure of a kilogram per square centimeter. The growing tendency toward the adoption of the C. G. S. system suggests the use of a consistent unit for this dimension also. Might not the pressure of a dyne per square centimeter be suitably called a *bar* (Greek *βαρος*, pressure, weight)? This suggestion is made because the practical use of a unit is always much facilitated by a definite verbal designation. In this case the pressure of a megadyne per square centimeter would be called a *megabar*, a name no more cumbrous than 'atmosphere,' and far more definite. This unit, though unnamed, has long been advocated by Ostwald (Grundriss Allgem. Chem., p. 54, 1899) as a more scientific one than the present standard. The megabar is 1,000 ÷ 980.6 = 101.98 per cent of a kilogram per square centimeter, or 101.98 ÷ 1033.2 = 98.703 per cent of an atmosphere, or the pressure measured by 75.015 centimeters of mercury at 0° C. at sea level, and latitude 45°. This pressure is more nearly the average atmospheric pressure at the laboratories of the world than the arbitrary 'atmosphere' usually taken. A megabar, acting through the volume of a cubic centimeter or milliliter, performs a megerg of work, or one-tenth of a joule."

2. [*Extract from* "The convection of heat from small copper wires." By A. E. Kennelly, C. A. Wright, and J. S. Van Bylevelt, in Proc. Am. instit. electr. eng., June, 1909, v. 28, p. 706.]

"*Air pressure in absolute measure.*—In column II of the foregoing table the air pressure in the tank is recorded in megabars. The C. G. S. unit of pressure, 1 dyne per square centimeter has been called the 'bar'; so that a megabar is 10^6 dynes per square centimeter. According to the recently published data of the Bureau International des Poids et Mesures (Les Recents Progrés de 1907, pp. 30-31), a column of mercury 760 mm. (29.92 inches) high, at sea level, in latitude 45°, exerts a pressure of 1.0132 megabars. Consequently 1 megabar represents the pressure of a column of mercury of 750.09 mm. (29.53 inches) under the same conditions. For most practical purposes, therefore, a megabar may be taken as 1 atmosphere. It is actually 0.987 of an atmosphere of 760 mm. [under apparent gravity] at sea level and 45° latitude."

3. STANDARD UNITS IN AEROLOGY.

By Prof. A. E. KENNELLY.

[Dated Cambridge, Mass., Mar. 25, 1914.]

In "Science" for March 13, 1914 (p. 391), Prof. Alexander McAdie calls attention to the confusion which is likely to be produced in scientific literature by the use of the term "bar" as a unit of pressure, with two distinct significations. I beg the privilege of indorsing in your columns the views there expressed, and of adding a few remarks.

It is generally agreed that the "bar" should be the name of a unit of pressure, in some simple numerical relation of dynes per square centimeter. The question is as to whether it should be applied to the C. G. S. unit (1 dyne per square centimeter) or to a pressure one million times greater. If it is given to the C. G. S. unit, then the standard atmospheric pressure, as hitherto adopted, would be the megabar of 750.09 mm. of mercury. On the other hand, if it is given to this latter standard atmosphere, then the C. G. S. unit of pressure would become equal to a microbar.

It is submitted that in view of (1) the history of the term, (2) of scientific consistency, (3) of existing usage, the "bar" should be adopted as the name of the C. G. S. unit, making the standard atmosphere a megabar.

History.—Prof. McAdie has pointed out that the term "barad" was proposed for the C. G. S. unit by a committee of the British Association in 1888. The International Physical Congress of Paris, in 1900, reported in favor of the "barie" as the name of the C. G. S. unit, (see vol. I of Proceedings, p. 100). The following is quoted from page 31 of Guillaume's "Recents Progres du Systeme Métrique" (Paris, Gauthier-Villars, 1907), a report presented to the Fourth Convention of Weights and Measures in Paris October, 1907:

Cette relation permet de calculer immédiatement la valeur en baries (unite C. G. S. de pression, egale à une dyne par centimetre carré) de la pression exercée par une colonne de mercure de la hauteur normale de 76 cm. dans les conditions de la pesanteur qui résultent de l'ensemble des stations considerées par M. Helmert. On trouve ainsi

$$P \text{ normal}=1013211 \text{ baries.}$$

On peut calculer aussi, en posant P égal a l'unité, la hauteur de mercure qui exerce l'unité de pression. On trouve ainsi 0.75009μ. La megabarie normale serait donc exerçée par une colonne de mercure de 750.09 mm., à la témperature de la glace fondante, sous la latitude de 45°, et au niveau de la mer; l'intensité de pesanteur pour laquelle la colonne de mercure, exerçant une pression égale à une megabarie serait de 750.09 mm. devrait avoir la valeur:

$$g=980.738 \text{ cm. sec}^{-2}.$$

In 1903 Prof. T. W. Richards independently originated and adopted the name "bar" for the C. G. S. unit of pressure in his chemical work.

Scientific consistency.—It is generally admitted that the C. G. S. system is the most generally and internationally recognized physical system of units in use at the present time, and the system most frequently employed in theoretical discussions of physical quantities. The system is strengthened when its unit magnitudes receive internationally recognized names. It necessarily becomes weakened when such names are assigned to unit magnitudes outside the system, even if decimally connected therewith. For example, the C. G. S. system

became weakened when the name "ohm" was assigned to an electrical resistance unit magnitude of 10^9 C. G. S. units, and when the "volt" was assigned to an electromotive force unit magnitude of 10^8 C. G. S. units; because in order to maintain a simple relation between these units, an entire system of corresponding unit magnitudes—the "practical" electrical system of the volt, ohm, ampere, coulomb, joule, watt, and henry—all distinct from the C. G. S. system, and so related, as Maxwell showed in his treatise, that the "practical" unit of length became equal to a quadrant of the earth, and the "practical" unit of mass 10^{-11} gram. If the C. G. S. unit of e. m. f. had been named the volt and the C. G. S. unit of resistance the ohm, engineers would be using megavolts for the present hundredth volt and megohms for the present thousandth ohm in their practical work, just as they actually use microfarads to-day, and the entire engineering system would have remained identical with the C. G. S. system. It is too late to make such a change to-day in electrical unit magnitudes; but we can hope to avoid such sectionalizing of units, in other and new directions, by keeping unit names in the C. G. S. system.

Usage.—The "bar" as the C. G. S. unit or 1 dyne per square centimeter has been used in various papers on physico-chemistry by Richards in this country [see 1 above], and also in papers of my own [see 2 above]. It also appears in recent textbook literature as the name of the C. G. S. unit.[1]

4. [*Extract from* letter by Prof. A. E. Kennelly, Cambridge, Mass., Apr. 6, 1914.]

"Many thanks for your kind letter of April 3, inclosing a most interesting Northern Hemisphere chart. The numerical values of the isobars [viz, millibars of Bjerknes] are so convenient on this chart that the question as to whether they should be called kilobars or millibars occupies a lesser place in the mind. I note that the statement is correctly made that these are given in standard pressure. If they were expressed as kilobars, they would not only be in standard pressure but also in absolute pressure. [See 5 below.] I was not aware that the use of the bar had been adopted officially by the United States Weather Bureau as a standard atmosphere. * * *" [See 6 below.]

5. The bar and millibar introduced into dynamic atmospherics by Bjerknes are simply names for pressures expressed in units of dynes per square centimeter, and are therefore *strictly* absolute units or *units of absolute pressure* in the C. G. S. system.—[C. A.]

6. The bar of Bjerknes, or the pressure corresponding to about 750 mm. of the mercurial barometer, is not proposed by the United States Weather Bureau nor by Bjerknes as a "standard atmosphere." The bar of Bjerknes, and its subdivisions, is used as a method of expressing the *absolute pressure in the atmosphere,* or the absolute pressure of the atmosphere at any place. The ordinary barometric reading, whether in millimeters or inches, expresses only the apparent pressure, and requires several corrections in order to express the absolute pressure.—[C. A.]

[1] Zeleny & Eriksen. A Manual of physical measurements. McGraw-Hill Book Co., New York, 1912, p. 220.

7. The C. G. S. system originally proposed to do away with all unnecessary, awkward, and arbitrary relations and names; it adopted a perfectly systematic series of elementary units, multiples, and combinations; the centimeter for length; the gram for mass; the mean solar second for time; each of these to be increased or diminished individually by powers of ten when any problem seemed to require the use of larger or smaller units. Eventually these new multiples and combinations, or derived units, began to be called by special names, as matters of individual pride or international courtesy, but many adhered strictly to the simple international and neutral C. G. S. system, and looked with disfavor on further innovations.

For instance, the C. G. S. unit of force is *one dyne,* or the force that can, by acting for one second on one gram, produce a change of velocity of one centimeter per second when the gram is free to move; this is a change of one unit in its momentum (which Newton called its quantity of motion) and is measured by the product of the number expressing its mass M, by the number expressing its velocity L/T, per second $1/T$. This algebraic expression is MLT^{-2} or $\frac{ML}{T^2}$

The C. G. S. unit of pressure is the pressure exerted by one dyne or 1 C. G. S. unit of force, pressing against or acting on every portion of a C. G. S. unit of area, or on one square centimeter. This C. G. S. unit of pressure may be expressed algebraically, $\frac{ML}{T}\cdot\frac{1}{T}L^2$; it is so used by many physicists in laboratory experimentation and has been called a *bar* by Ostwald, Richards, and others.

On the other hand, Bjerknes proposes a unit of pressure for use in atmospheric dynamics and recommends the pressure exerted by 1,000,000 dynes acting upon unit area of 1 sq. cm.; this he also calls a *bar*. Hence, the bar of Bjerknes is 1,000,000 times the C. G. S. unit or bar of the physicist. The 1,000th part of the Bjerknes *bar* is his *millibar*, or 1,000 times the unit *bar* of the physicist. The *bar* of Bjerknes is sufficiently large to be convenient in atmospheric studies, while the *bar* of the physicist seems more appropriate for special laboratory studies; hence the unit suggested by Bjerknes has been adopted by the recent international meteorological and aerodynamic congresses although it represents a slight departure from the established C. G. S. system of nomenclature, whereas the units adopted by the physicists agree precisely therewith. Fortunately, the *bar* of Bjerknes is the megabar or simply $10^6 = 1{,}000{,}000$ times the small unit of the physicist so there need be no confusion in the thoughts, or in the equations of the respective departments of physics, and until the various international authorities agree on appropriate names we have only to remember that the *bar of Bjerknes* represented by B, or *Bjer* or *Bjr*, and that of the physicists represented by b in the C. G. S. system, have such a ratio that the relation between the two is $B = b \times 10^6$ or $\mathrm{Bjr} = 1{,}000{,}000\ b$ or $1\ b = \mathrm{Bjr} \times 10^{-6}$.

Meteorologists need to discuss the motions of the atmosphere by using the absolute units quite as much as is done by other physicists in respect to problems in engineering, electricity, etc. We still adhere to dynes and fundamental absolute units. It is convenient for some to speak of the C. G. S. megabar as a million dynes per square centimeter, while others find it convenient to call it one bar. The bar of Bjerknes is not a "standard atmosphere," nor do we for a moment presume to alter the definition of a standard or absolute or normal atmosphere whenever physicists have occasion to use that

term for a unit which departs so much from the C. G. S. system. We agree entirely with the spirit of the recommendation adopted by the British Association for the Advancement of Science, 1898; Ostwald, 1899; and the International Congress of Physicists, Paris, 1900; all of whom appear to agree that the so-called "standard atmospheric pressure" (760 mm. of pure mercury under standard gravity at sea-level and latitude 45°) is not always the most appropriate datum for use.

In this connection we note that P. W. Bridgman (Phys. rev, Lancaster, Pa., (2), Feb., 1914, v. 3, p. 126, ffg) finds it convenient to use as his C. G. S. unit of pressure not dynes per square centimeter, but kilograms per square centimeter and the corresponding kilogrammeter per gram instead of gram-calory per gram.—[C. A.]

THE C. G. S. SYSTEM AND METEOROLOGY.

By Prof. VILHELM BJERKNES, Leipzig.

[Translated from Meterologische Zeitschrift, Februar, 1913, p. 67-71.]

The International Commission for Scientific Aeronautics at its meeting in Vienna (1912) adopted the following resolution:

In the publications of the International Commission the pressure will be expressed in *bars* or in decimals thereof, such as *decibar*, *centibar*, *millibar*, instead of in millimeters of mercury; this decision will however first become effective when the International Meteorological Committee shall have communicated its agreement therewith.

* * * * *

The principal advantages of the C. G. S. system were not considered during the discussion in Vienna, but were considered by all present as well known and recognized. But the subsequent discussion has shown that even on this point there prevails a surprising confusion. It will therefore not be improper to consider the question when we can apply entirely arbitrary units without injury, and when we can not relinquish the advantages of the C. G. S. system.

So long as scientific work consists only in the registration of individual elements and the statistical discussion of the resulting numerical series, we can without harm choose the units for the individual quantities quite arbitrarily—we merely need to apply the same units at various times and places; it is in this case quite unimportant whether the units thus applied to different quantities belong to a systematic system of units.

But so soon as we pass from climatological to dynamic researches we have to meet very different demands in order to understand the quantitative relations between the different quantities. For instance, we then no longer observe the pressure in order to consider the pressure itself, but in order to compute from it accelerations and velocities; we determine forces and motions not because of interest in these quantities themselves, but in order to compute from their combinations the work that is done and the heat that is evolved.

The conditions hitherto prevailing in meteorology have been very unfavorable for the development of this dynamic side of atmospherics. The equations of dynamics and of thermodynamics relate to the three dimensions of space and remain indefinite so long as we introduce into these equations only the results of observations obtained in two dimensions. With the establishment of aerology, these conditions have entirely changed. Simultaneous aerological observations give all the data needed for the direct application of the equations of dynamics and thermodynamics to meteorological problems, and thus open a prospect for an unsuspected development of meteorological science. But this development is restricted in its most sensitive portion as long as we retain an irrational unit of pressure for our simultaneous aerological observations. A single example will suffice to show the confusion that enters into dynamic equations as soon as we fail to apply a coherent system of units.

The condition of equilibrium in the atmosphere is as follows: The pressure against the boundary surfaces of any arbitrary volume of air must have a resultant that is directed vertically upward and is equal to the weight of the volume of air. If we consider a unit volume of this air, then its weight is equal to the product of its density ρ into the acceleration of gravity g. The resultant of the pressures against the boundary surfaces of a unit of volume we call the pressure gradient G (the dynamic definition of the gradient) and the equation of equilibrium takes the form

$$G = -\rho g \quad \text{(a)}.$$

The pressure gradient G may also be defined simply as the change of pressure per unit of length which is the geometrical definition of the gradient. Therefore, if z is a distance or length measured along the vertical, we have

$$G = -\frac{\partial p}{\partial z} \quad \text{(b)}.$$

Now (a) and (b) are the classic equations to which we are led under the condition that we are using a coherent system of units like the C. G. S. system.

But if we express the pressure in millimeters of mercury and retain the C. G. S. units for the density and the acceleration of gravity, then the equations (a) and (b) no longer harmonize but are incompatible with each other and clash together, and one or the other must be modified. If we decide to retain the geometric definition (b) for the gradient, then the equation of equilibrium (a) must be written in the form

$$1.333193\, G = -\rho g \quad \text{(a')}.$$

The property of the gradients as simply equal numerically to the product of density and acceleration of gravity, is thus ignored.

If, on the other hand, we decide to hold fast to the dynamic definition of the gradient as in equation (a), then the geometric definition of this quantity must be expressed under the form

$$G = -1.333193 \frac{\partial p}{\partial z} \quad \text{(b')}.$$

In this equation the gradient loses its property of being equal to the negative of the change of pressure. Whichever way we may decide it is evident that we lose the simplicity and harmony of the systems of equations (a) and (b).

Confusions of this or a similar kind will be introduced into every dynamic or thermodynamic equation that contains the pressure, and uses millimeters of mercury as the unit of pressure while at the same time retaining the C. G. S. units for all other quantities. In order to realize the extent of this class of difficulties with which dynamic meteorology will be burdened so long as we continue to use the millimeter of mercury as the unit, it suffices to write out in full the equations that come into use in dynamic meteorology.

In these equations the independent variables are the time, t, and the coördinates x, y, z.

The components of the active forces are represented by X, Y, Z, which in the most general cases are compounded of the force of gravity, the deflective force of terrestrial rotation and the force of friction; their potential is Φ.

The dependent variables are the following seven quantities:

u, v, w, the three components of the velocity of the air.

p, the pressure of the air.

ρ, the density of the air.

θ, the absolute temperature of the air.

r, the moisture (i. e., vapor pressure per sq. cm.) of the air.

These seven dependent variables satisfy the seven equations that are written below. In Scheme I they are given in the classical form that they take when using the C. G. S. system. In Scheme II they are given in the form that they assume when we express the pressure in millimeters mercury, but retain the C. G. S. units for all other quantities.

The equations are as follows: The three hydrodynamic equations (1), (2), (3); the equation (4) of hydrodynamic continuity; the equation (5) of the gaseous condition; the equation (6) for the conservation of energy; the equation (7) that follows from the second law of thermodynamics. Besides the quantity of heat dQ, added to the mass of air under consideration, these two last equations contain two other new quantities, i. e., E, the energy, and S, the entropy, of the mass of air. The fact that these are known functions of the variables p, θ, r, is expressed by the equations (6′) and (7′).

SCHEME I.		SCHEME II.
$\rho\frac{du}{dt}=-\rho\frac{\partial\Phi}{\partial x}-\frac{\partial p}{\partial x}$	(1)	$\rho\frac{du}{dt}=-\rho\frac{\partial\Phi}{\partial x}-1.333193\frac{\partial p}{\partial x}$
$\rho\frac{dv}{dt}=-\rho\frac{\partial\Phi}{\partial y}-\frac{\partial p}{\partial y}$	(2)	$\rho\frac{dv}{dt}=-\rho\frac{\partial\Phi}{\partial y}-1.333193\frac{\partial p}{\partial y}$
$\rho\frac{dw}{dt}=-\rho\frac{\partial\Phi}{\partial z}-\frac{\partial p}{\partial z}$	(3)	$\rho\frac{dw}{dt}=-\rho\frac{\partial\Phi}{\partial z}-1.333193\frac{\partial p}{\partial y}$
$\frac{1}{\rho}\cdot\frac{d\rho}{dt}=\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}$	(4)	$\frac{1}{\rho}\cdot\frac{d\rho}{dt}=\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}$
$\frac{p}{\rho}=R\theta$	(5)	$1.333193\frac{p}{\rho}=R\theta$
$dQ=dE+pdv$	(6)	$dQ=dE+1.333193pdv$
$dS\gtrless 0$	(7)	$dS\gtrless 0$
$E=f(p,\theta,r)$	(6′)	$E=f(1.333193p,\theta,r)$
$S=F(p,\theta,r)$	(7′)	$S=F(1.333193p,\theta,r)$

These two systems of equations I and II differ from each other only in that no numerical factor enters the first set, whereas in the second set the numerical factor 1.333193 occurs everywhere in connection with the pressure. It is very evident that this factor causes an increase in the labor of computation. However, this inconvenience is only a small matter. The important objection to this second system of equations consists in the confusion of ideas introduced by this numerical factor. The nature of the confusion is illustrated by the above given example where we have considered the definition of the gradients. But the subject of this confusion is by far not exhausted by this one example; it recurs in innumerable varying forms, with every form of the equation.

It will not be possible to form clear plans for a fruitful coherent systematic development of observational and theoretical meteorology, unless we first consider carefully at every step how the above mentioned confusions are to be put aside or circumvented in the best way possible.

It must not be forgotten that the question here presented has an importance far beyond the limits of meteorology. The C. G. S. system has been planned as a universal system of units, and its universal application can not be prevented in the long run. At the present time we all regret that synoptic meteorology did not, at its very foundation, adopt the unit of pressure of this system. It is easily understood why at the present time and as conditions now exist, the general transfer of all meteorology to the C. G. S. system is delayed. The expenses and inconveniences that accompany the general transfer are very considerable, and the advantages will only be appreciated and become of great importance when the transfer has become really universal. Therefore it may still be proper to await the time when the British Empire and the United States shall have adopted the metric system.

But the conditions in regard to aerology are entirely different. This is a new branch of meteorology that is now in a stage of most rapid development and in which we can not afford to lose the benefit of the C. G. S. system, at least in the theoretical discussion of simultaneous ascensions of kites and balloons. It is of the greatest importance for the rational development of this branch that we allow ourselves the freedom of utilizing the advantages of the universal C. G. S. system.

PROGRESS IN METEOROLOGICAL OPTICS DURING 1912.[1]

By CHRISTIAN JENSEN, Hamburg.

[Translated by C. Abbe, jr., for the MONTHLY WEATHER REVIEW.]

During the year 1912 the occurrence that attracted the greatest attention was the general turbidity of the atmosphere. This unusual condition has shown itself in the low degree of saturation of blue skylight (1), the intense red coloring of the sun when near the horizon, the weakening of s arlight (2), the phenomenon of Bishop's Ring (3), and by other phenomena apparent to the naked eye. The most striking evidence, and of a quantitative character, was afforded by the instrumental measurements of the intensity of insolation and of sky polarization. We shall first review those publications of the year 1912 which deal with this atmospheric turbidity, but it will sometimes be necessary to touch upon studies made during the year 1913 also.

It is generally agreed that the tremendous explosions of the volcano Katmai in Alaska from June 6 to June 9, 1912, produced the exciting cause of that optical disturbance whose principal effects over Europe began on June 20 of that year. But as we have already pointed out (4) the fact must not be overlooked that reports of antecedent optical disturbances at various points, indicate that there was a preexistant condition of general turbidity. Thus the well-known investigator of the zodiacal light, Schmid (5) of Oberhelfenswil, reported that in the second half of May the sun was the center of a peculiar silver-white disk 8° to 10° in diameter; F. Hahn (6) reports that as early as June 8 he noticed the peculiar

[1] From Mitteilungen der Vereinigung von Freunden der Astronomie und kosmischen Physik, Berlin, 1913, pp. 166-183.

appearance of the western sky at a little before sunset, and Addison (7) noticed the remarkable appearance of the heavens at Riga as early as the middle of May. It is specially noteworthy that Eginitis (8) at Athens found the sunshine recorders there indicating a striking drop in intensity at the early date of April 7, followed throughout May by further decrease, after which the intensity increased until the middle of June when it again diminished to the end of the month. E. Barkow (9) reports an atmospherico-optical disturbance observed in the Antarctic, appearing as an unusual twilight. The first record of this twilight was a journal entry of June 15, and the exact time of first appearance of the disturbance can not be given. The general result of all available reports on this turbidity strongly suggests that there were two clearly defined phases in this phenomenon of 1912, and that its cause is to be sought not only in the explosion of Katmai but also in some cosmical cause which was superimposed upon the former from June onward.

The twilight phenomena and Bishop's Ring of the last great disturbance have differed considerably from those that accompanied the explosion of Krakatoa and the West Indian volcanoes, and in consequence new problems have accumulated. So far as Europe is involved, pronounced twilight phenomena began (10) about June 20 and continued for some time. Schmeel (11) reports beautiful colorings as early as June 18 and even on June 11. After this date more or less brilliant twilights occurred at greater or lesser intervals (12), but the experience of former years would have lead us to expect much more frequent brightly colored phenomena. P. Gruner (13), of Bern, has published the results of systematic studies of these and similar phenomena, whence it appears that in Switzerland also the purple glow was very weakly developed throughout the late summer, not regaining its intensity until autumn.

Kimball (14) found a pronounced falling off in the atmospheric transparency at [Mount Weather, Va., 45 miles northwest of] Washington, D. C., from the morning of June 9 to that of June 10. Hand in hand with this went a relatively low degree of skylight polarization (15) for those points in the sky lying in sun's vertical and at 90° solar distance. He also points out the strikingly large daily variations in the degree of polarization and in the atmospheric transparency, as well as anomalous positions of the Babinet point. His first effort was to explain all these anomalies by special local meteorological processes; but when the opacity had endured until the end of August, even though variable in intensity, Kimball felt obliged to modify his views. In a footnote to (14) he presents a table of skylight polarizations and of solar radiation intensities as measured with an Ångström pyrheliometer,[3] and expresses the opinion that the first-mentioned turbidity, except on certain occasions, might also be due to the explosion of the Alaskan volcano. When other things are equal one may say that intensity of insolation increases with the altitude of the sun above the horizon, so that by examining the charred line of a Campbell-Stoke sunshine recorder one may form some idea of the intensity of the sun by noting the time or altitude at which its records begin from day to day. W. Marten (16), A. Stöhr (17), and Eginitis (18) have made such studies. Marten determined the relation between the sunshine recorder and the Ångström pyrheliometer, and then found that even for solar altitudes of 50° to 60° the decrease in the intensity of insolation amounted to about 0.35 gr.-cal. per cm². per hour, the radiation intensity of a normal year being 1.25 to 1.35 gr.-cal. as compared with 0.8 to 1.0 gr.-cal. during the summer of 1912.

Further, Marten pointed out remarkable variations in intensity, which indeed seem to show up in measurements of positions of the neutral points of polarization and call for more thorough investigation. It is evident that one may attempt to explain these variations by supposing corresponding fluctuations in the cause of the turbidity, thus referring them to a general phenomenon, or one may refer them to the effects of local influences. Thus Hildebrandsson (19) would refer a decrease in the turbidity observed at Gothenburg on July 21 to the temporary clarifying of the air by thunderstorm disturbances. But in this connection I would point out that A. Wigand (20) made a balloon ascension on September 28, 1912, whereby he was able to determine that, aside from a vapor veil lying just above the stratus cover and below 1,000 meters, there was 750 meters of intense haze lying at an altitude of 5,000 meters and that up to 9,100 meters there was an increased haze content which reduced the normal visual transparency of the atmosphere. Wigand thinks the haze stratum must have been due to the presence of foreign particles of various sizes, which had gradually settled from altitudes above 10 km. Perhaps these various strata also indicate some relationship with the increasing probability of the two-fold character of the disturbing cause. The extent to which the clouding particles might serve as condensation nuclei for raindrops is closely related to the problem of a meteorological origin of the haze. One is tempted to connect the strikingly heavy precipitation of the second half of 1912 with the loss in atmospheric transparency. So far as I know this was first suggested by Gockel (21), but it seems that it must be abandoned to a certain extent at least. Wigand (22) made a balloon ascension on January 5, 1913, reaching an altitude of 7,000 meters, and observed a considerable weakening of sunlight due to a high haze which yielded an extremely low number of condensation nuclei when examined with an Aitken dust-counter, and hence could not be regarded as a normal mass of vapor.

In August, 1912, Fr. Busch (23) drew attention to a change in the sky light polarization observed by him on July 14, particularly emphasizing the marked increase in the solar distance of the neutral points for positive altitudes of the sun, and the strikingly small solar distance of Arago's point for the sun at −0.5° altitude. At the same time he pointed out the reappearance of Bishop's Ring and the very insignificant development of the purple glow. Unfavorable weather prevented both Busch and myself from securing measurements at the first appearance of this disturbance. The striking decrease in the solar distances of the neutral points for the smaller positive and not too great negative altitudes of the sun, as indicated by the reports from all over the world, Jensen has (23) compared with the strikingly great increase in the zenithal polarization as found by Pickering and Kimball for the greatly disturbed years 1884, 1902, and 1903. Jensen has discussed the cause for these phenomena in another place (24). Referring to these results we would add that, contrary to the experience in undisturbed periods, several series of measurements almost uniformly showed that on interposing a blue or green filter before the polariscope smaller solar distances were found than on using a red filter. The author found these results to be in good agreement with

[3] Marvin pyrheliometers were used at Mount Weather.—Translator.

the naked-eye observations of changes in sky-color due to the haziness, as well as with Dorno's (**25**) observations, communicated to him by letter, upon the relations between the measured intensities in the different colors of diffuse sky light and of direct sunlight. The latter relation depends upon the ratio of the positive to the negative component of vibration at various points in the sun's vertical. So far as the total brightness is concerned, Dorno found an average decrease in the intensity of the direct insolation, due to the disturbance, while the total radiation (Sun+Sky) showed quite unchanged magnitude. Therefore we must conclude that there was an increase in intensity of the diffuse sky light. The observations of the different colors show that both the direct sunlight and the diffuse sky light have lost decidedly more in the green than in the red, but the difference is most pronounced for the sky light. The ultraviolet solar radiation, as measured with the zinc-ball-photometer, showed specially large decrease (40 per cent as compared with 18 per cent loss in the thermal radiation and 20 per cent in the brightness) but the solar spectrum showed that the composition of the ultraviolet rays remained unchanged, whence Dorno concludes that the disturbance is not to be ascribed to the presence of any substance loaded with absorption lines in this portion of its spectrum.

The second occasion, which drew forth a series of important studies, was the solar eclipse of April 17, 1912. Weber and Borchard (**26**) made a set of observations of the sun's brilliancy in the red and green spectral regions, using an opal-glass photometer, and they also observed the so-called Ortshelligkeit, i. e., the illumination of an opal-glass plate produced by the light from the whole sky falling upon it. This material was particularly used for checking up Vogel's earlier measurement of the decrease in brilliancy from the center to the limbs of the solar disk. The observations in the red agreed very satisfactorily with those by Vogel; but those in the green show a slight discrepancy which remains to be explained. Werner (**27**) compared the decreasing brightness of the sun, as measured with a spectro-photometer for wave lengths 443, 514, and 651 $\mu\mu$ by Kron at Potsdam, with calculated values for the brightness of the solar sickle at any given phase of the eclipse and assuming the correctness of Vogel's law for the radial decrease in luminosity of the solar disk. Observation and computation agreed well for the wave length 651 $\mu\mu$, but for longer wave lengths there appeared discrepancies which the author ascribes primarily to the action of the diffuse sky light necessarily present when observing the sun; as stated by Rayleigh's Law, this action of diffuse light is specially pronounced in the regions of the shorter wave lengths as it varies inversely as the fourth power of the wave length. Werner finds no reason for doubting his initial formula, and would also explain a part of these discrepancies by assuming that the atmosphere was more transparent during the first half hour of the eclipse than subsequently; but we can not agree with him in this case. In the first place, the weather notes he himself publishes, wherein it appears that cirrus came over after the maximum phase of the eclipse had passed, seem to testify against such an assumption; in the second place the observations by Elster and Geitel (**28**), evidently made under similar weather conditions, seem to contradict the assumption. It is true the measurements of the latter observers, made with an electric-light photometer that was fairly sensitive throughout the whole visible spectrum, indicate a probable slight decrease in transparency, but certainly do not show a more rapid increase in the insolation after the middle of the eclipse. The assymetry of the curve of total radiation during the eclipse, observed by Walter and Goos (**29**) on this occasion as also by Cirera on a former one, is interpreted by Elster and Geitel as showing a certain amount of hazing of the atmosphere within the moon's shadow, hence the direct insolation was weakened to a just barely noticeable degree while the sky illumination was so greatly increased that the total illumination became greater than it had been before the eclipse. This reads as indeed rather plausible, but it is interesting to here recall that Dorno's measurements on the great disturbance of 1912, to be sure a haze of wholly different character, showed that the latter had not caused any change in the total illumination.

Of the various photographs made from balloons during the eclipse those showing the balloon's shadow, as taken by A. Wigand and E. Everling (**30**) and by M. Seddig (**31**) are particularly noteworthy. Gimpel's explanation (**32**) of the sickle-shaped balloon shadow is practically the same as those by Wigand and Everling and by Seddig. Wigand and Everling conceive a point of light at infinity giving a circular shadow upon the plane of projection (the earth's surface) and hence the whole luminous surface (the sickle) giving a multitude of such circles arranged as the geometrically similar inverted image of the sickle. A graphically derived curve of equal shadow densities shows good agreement with the determinations of the distribution of brilliancy.

Werner (**27**) when estimating the amount of diffuse sky light that gets into measurements of the sun's brightness, employed the values found by Diercks (**33**) in his study of the brightness of the sky in the vicinity of the sun. One must consult the latter paper to understand what success Diercks had in stopping out all radiation other than that which he wished to measure photometrically from some smallest possible segment of the sky close to the sun, and at the same time determining as accurately as possible the interval between it and the sun's limb. Observations made on some specially clear summer days in 1911, showed uniform decrease in illumination from the sun's limb to a distance of $7\frac{1}{2}°$ both to the right and to the left of the same. The normal change was determined analytically with great accuracy by the aid of empirical elliptic equations. Of marked meteorological significance, with reference to further applications of this very exact method, appears to be the well-marked relationship between the above-mentioned segment brilliancy (Flächenhelligkeit) and the Ortshelligkeit minus the direct solar rays, which is an index of the degree of saturation of the blue sky light and of the purity of the air. I should also mention a surprising interruption in the normal course of the decrease in brightness with distance from the sun, a so-called swelling that Diercks describes as a "Hof" about the sun and whose existence could only be demonstrated by the aid of the photometer. The thought is at once suggested that such measurements may in the future furnish a means of detecting weakly defined atmospheric disturbances of both local and general nature.

On Teneriffe, G. Müller (**34**) and E. Kron have undertaken a very valuable investigation. After the appearance of Abbot and Fowle's recent bolometric determinations of the phototransparency of the atmosphere, Müller had long intended to carry out spectro-photometric measurements of the absorption in order to determine the spectrum distribution of the sun's energy at points without the earth's atmosphere. Pannwitz's

expedition to observe the transit of Halley's comet offered Müller a very welcome opportunity. The most important measurements were made with a slightly modified Glan-Vogel spectro-photometer at 1,950 meters (near Pedrogil Pass), and at 3,260 meters (Alta Vista). He succeeded in determining with great accuracy the local transparency for 11 different wave-lengths and in securing the energy curve for the visible portion of the solar spectrum. First, he determined the distribution of brightness of the visible portions of the solar spectrum by means of a standard comparison lamp. In order to compare the distribution of energy in this portion of the spectrum, the distribution of energy for a so-called black body, he had to compare the standard lamp with the artificially blackened black body, and this could not be done until after his return from Teneriffe. It was constantly borne in mind that the incandescent standard lamp might undergo changes during the period the expedition lasted, and the greatest care was exercised in all measurements and computations. Finally Müller employed Wien's shift law and Planck's radiation equation in an effort to determine the absolute temperature of the sun's surface by means of the extra-atmospheric energy distribution of the solar spectrum. He found the values 6,283° and 6,332°, respectively, by the two methods, values which agree satisfactorily with those recently found by Kurlbaum from observations made in upper Egypt. It is noteworthy that in general the coefficient of transparency varies directly with the wave-length, but that every curve showed a slight bend in the central region of the spectrum, a phenomenon which Schuster had already pointed out as characteristic of Abbot's values. Since the air above the Teneriffe stations is abnormally dry, this interruption in the otherwise uniform decrease in transparency with decreasing wave-length can not be explained as due to selective absorption by water vapor. Besides, as Müller points out, Abbot's latest measurements on Mount Whitney, though not known to Müller at the time, seem to show that the selective absorption between 560 and 580 $\mu\mu$, which is still clearly marked in the measurements at Alta Vista, seems to have disappeared at the summit altitude of 4,420 meters.

During the past year K. Bergwitz (**35**) made balloon ascensions to determine the atmospheric coefficient of transparency for blue-violet rays, using the newest Elster-Geitel cells. In these cells the light falls upon a negatively charged, photosensitive layer in the high-vacuum chamber and thereby sets free electrons which make the vacuum conductive. This conductivity may be measured by means of appropriate devices, and it is found that the strength of current due to the individual wave-lengths is proportional to the intensity of the incident light. In the present case the cell was fitted with a sheet of Jensen blue glass to limit the region of wave lengths, and the current was measured by means of a Kadelbach and Randhagen box galvanometer. The well-known Lambert-Bouguer formula was tested by measurements at different altitudes of the sun, with a very satisfactory agreement between observed and computed values. Bergwitz found the coefficient 0.47 for blue-violet rays, a value differing slightly from that determined by Schünemann in Wolfenbüttel a few days earlier. However, Bergwitz showed that the sign of the discrepancy was the one to be expected under the plausible assumption that blue-violet rays are more strongly absorbed in the lower than in the higher layers of the atmosphere. As was pointed out in our review for 1911 (**36**), this coefficient enables us to compute the number of molecules in a unit volume of a given gas. Dember (**37**) therefore endeavored to secure the Loschmidt numbers, i. e., number of molecules in 1 cm³. of gas at 0° and 760 mm., by means of a transparency coefficient also determined by an Elster-Geitel cell. To do this one must determine the Rayleigh relation between the intensity of the incident light, the intensity of the ray transmitted by a definite atmospheric layer, the thickness of that layer, the wave-length of the incident light, the index of refraction of the scattering particles, and their number per cm³. Homogeneous light must be used because the effect of the larger particles increases as the sun's altitude decreases, and to secure this Dember combined a spectrometer with an Elster-Geitel photometer in which the Uviol-glass cell was replaced by an alkali cell fitted with quartz covers to transmit the shorter wave lengths. The magnitude of the photoelectric effect was measured by means of a unifilar-electrometer. His measurements of August 24, 1912, made on the Signalkuppe (4,560 m.) of the Monte Rosa massiv, gave a mean coefficient of 0.4 (0.54 for blue-violet, 0.32 for ultraviolet), corresponding to the Loschmidt number $n = 1.25 \times 10^{19}$. The author explains the difference between this value for n and that found by Millikan (2.7×10^{19}) in his investigations of unit charges, by the effects of water vapor, of ozone, and of minute snow crystals. He has here lost sight of the fact that, although he describes August 24 as being a perfectly clear day in a period of otherwise quite unfavorable weather, the general haziness of the atmosphere had already been long since markedly effective in the Alps. However, these measurements encourage us to hope that the extremely sensitive photoelectric photometer will find further application in such investigations.

We should mention here the daily noonday radiation measurements carried out in 1911 by G. Raymond (**38**), who measured the photoelectric effects by means of an accurately described zinc amalgam receiver. He determined the time required by the insolation to dissipate a definite and uniform negative charge. The sensitive surface was not exposed perpendicular to the sun's rays, but was always kept in a horizontal position, so that the observed values had first to be reduced to those for perpendicular incidence. We have not been able to understand from the paper cited whether Raymond attempted to exclude and how far he succeeded in excluding the effects of diffuse sky light. Dorno's work, "Studie über Licht und Luft des Hochgebirges" (**39**), so far as it treats optical conditions, is concerned with measurements both of solar radiation intensities and of the radiation from the whole sky (sun + remaining sky). An article by him (**40**) in 1912 points out that by using the better known meteorological elements his measurements at Davos may be extrapolated to cover all other similarly situated localities in the Alps. He finds that a physically adequate idea of the photometric and atmospheric climate of large regions might be secured by carrying out at a few other places the supplementary work which he carefully describes. Finally he presents positive accurate suggestions for selecting the points at which definitely described radiation observations are to supplement those in atmospheric electricity.

Humphreys' (**41**) interesting investigations into the so-called "earth light" have a purely theoretical significance. Some years ago Yntema came to the conclusion that the light of the nocturnal sky, disregarding that due to direct starlight, was referable in part only to atmospheric diffusion or scattering while the by no means small remaining portion was to be referred to a kind of perma-

nent aurora. It is rather notable that in his observations made at sea-level he found that the increase in brightness from zenith to horizon was by no means constant either from night to night nor even throughout the same night. Abbot made a corresponding study on the summit of Mount Whitney (4,400 m.) and obtained essentially the same results as those of Yntema. Humphreys concludes from this that the "earth light" is some general phenomenon of the upper levels of the atmosphere. He objects to Yntema's view that it is of auroral character by pointing out that there is no evidence that the phenomenon is relatively stronger in those regions where the aurora is particularly well marked. On the other hand, he points out in detail how it would be possible for a bombardment by meteoric dust, moving at an average rate of 42 km. per second through the atmosphere, to produce a general luminescence of the atmosphere due both to the high temperature resulting from the compression of gases and to an ionisation similar to that resulting from bombardment by α-rays. It is evident that, in view of the necessary absorption, the meteoric particles must penetrate to a considerable distance within the outer more tenuous layers of the atmosphere in order to produce a sufficiently pronounced luminescence, consequently Humphreys finds that a direct variation of brightness with zenith-distance is in good accord with his theory. He further tests the same by computing the consumption of energy required to produce the observed brightness, and reaches the result that previous estimates of the amount and velocity of precipitated meteoric material would provide more than enough material to produce the observed effect.

Personally the reviewer is specially pleased to record very satisfactory advances in the field of atmospheric polarization. Plassmann (**42**) has given us a beautiful contribution in which he determined with tireless and most painstaking care, the exact times and positions of the Arago and Babinet points for both evening and morning hours from March 26, 1910, to October 18, 1911, employing a Jensen pendulum-quadrant. Except for a few series made at Oberkirchen an der Lenne (450—460 m. alt.) his observations relate to Münster. As Plassmann himself says, he presents this abundant material just as it comes from the observations, and leaves its application to meteorologists. Many results may be expected when this rich material has been worked up. Plassmann generally combines 5 individual observations—sometimes 3, 4, or 6—and computes the sun's mean altitude for the pentad, the solar and antisolar distances for the neutral points. Then he combines each ten mean solar distances according to decreasing solar altitudes, and computes the final mean solar distances for each solar altitude. In this work he has used all the series of observations, including some that are obviously much influenced by clouds. In the nature of the case, the time intervals between the individual values which have been combined into pentads may sometimes be quite considerable, so that Busch (**43**) is quite justified in referring the absence of a regular march in Plassmann's final values to this fact in part. As a matter of fact it appears that when he computed the values by a method explained below, and omitted a specially disturbing series, the jumps in values disappeared. These computations showed a minimum solar distance for the Arago point with the sun at $-1.5°$; the distance of the Babinet point increased from a small positive up to the maximum negative solar altitude without showing a maximum at sunrise or sunset, thus agreeing with Jensen's measurements for the first half of 1909. The method introduced by Busch and adopted by us as well as by many other observers, is to combine all observations made for sun's altitudes $n.9°$ to $n°$ and refer them to sun's altitude $n.5°$, and observations $-n.1°$ to $-(n+1)°$ are referred to sun's altitude $-n.5°$; for example, under the altitude 3.5° are grouped those from 3.9° to 3.0°, and under $-2.5°$ are grouped those from $-2.1°$ to $-3.0°$. Disregarding the minutiæ of the curve, this method has shown itself a very practical one and in view of the increasing scope of these observations it is to be earnestly hoped that the method may find general adoption for the sake of uniformity. Plassmann makes some very interesting remarks about the residual interference fringes sometimes seen after closing his evening observations, when all the uncolored bands seem to cross the field of view without interruption. This phenomenon was so distinctly pronounced that Plassmann could project the subjective and objective images against the sky, where the positions of identifiable stars enabled him to determine equality in width of the two sets of images. Plassmann (**44**) communicates some of the measurements of solar distances in another place also, where he particularly contributes an elegant, easily comprehended guide to observations on the neutral points, specially adapted to the needs of the navigator who is less familar with the phenomena. The neutral zones of water surfaces for low positions of the sun discovered by Jensen (**45**) have been discussed in connection with the neutral points of the sky.

My review for the preceding year noticed Platania's first observations in Catania. Fortunately he has continued to zealously observe the neutral points (**46**). A comparison of the mean values from his observations for 1910 and 1911 with the corresponding ones obtained by Busch shows the solar distance of these points was generally somewhat less during 1911 than 1910 in Catania as well as in Arnsberg. We will not here consider the degree of influence possibly exerted by the strikingly clear skies of the summer of 1911. Platania concludes, from the slight difference between the means for Arnsberg and for Catania, that local conditions have but slight influence on the solar distances when observations are made under perfectly clear skies. But in view of the emphasis laid by so many observers upon the relation between local conditions and skylight polarization, his conclusion must be regarded as rather venturesome.

As pointed out last year, a consideration of the turning points in the regular march, and the jumps in the march of the neutral points led Süring to the conclusion that there is here an influence such as that of strata-boundaries at definite atmospheric levels. Humphreys (**47**) has tested the possibility of the existence of such boundaries as Süring assumed for his explanation, and finds that dust layers are actually to be expected at the levels of 1, 4, and 11 km. as given by Süring. The lowest layer would consist of relatively heavy dense dust carried by surface winds; the second layer of lighter, less dense particles and resulting from vertical currents; and the third layer, the least dense, is referred to action of cyclonic currents. Finally Jensen (**48**) points out that a study of the recent computations of observations by himself and many others, is far from affording any grounds for doubting the relation pointed out by Busch in 1893, existing between the sunspot period and the secular variation in the solar distances of the neutral points.

This seems the best place to introduce a notice of Heim's (**49**) elegant little book presenting lectures before the Alpine Club, although it is a remarkable and regrettable fact that he does not touch at all upon the interesting and important polarization phenomena. In this work he comments inspiringly and beautifully on the peculiarities of the atmospheric colorings, their causes,

the so-called blue and the yellow distances [die sogenannte blaue und die gelbe Ferne], the color of the sky and the stars, the colors and duration of twilight and of Alpenglow. In considering the zodiacal light Heim relies principally on the later observations by Schmid. Noctilucent clouds and Bishop's Ring are briefly considered, and summary treatment is also accorded both solar and lunar halos and coronas, mirages, etc. He dwells lovingly upon the causes for the peculiarities in the air colorings, setting forth in detail how the air appears as a blue veil when it is projected against a weakly illuminated background, or acts as a red-yellow glass when projected against a strongly illuminated surface that may or may not be self-luminous. He discusses atmospheric perspective, the yellow and the blue distances, and shows how combinations of the two effects may produce a great variety of tones. His somewhat original train of thought can not be considered in detail here. Twilight and allied phenomena are treated at length, and many colored plates show the gradual changes in the illumination of the Glärnisch with its sky background, seen from the Zurichberg as the sun sinks from $+4°$ to $-4°$. This and another splendid series of color plates from the brush of the author, increase the pleasure which this little book, popular in the best sense of that word, gives to the reader. Full of enthusiasm for nature's beauties, few readers will regret purchasing it.

We now come to a series of publications in meteorological optics during 1912, most of which are of special scientific significance, but as nearly all of them treat subjects of purely meteorological interest we must be content with a brief survey of their content. Many readers already know that Forel solved the problem of the Fata Morgana over the Lake of Geneva. He was able to demonstrate that the phenomenon occurs at the point of transition from refraction over relatively warm water to refraction over relatively cold water, that is between two regions of opposite refractive conditions. A later more detailed memoir (**50**) shows that there is by no means a slow gradual change from the one type of refraction to the other, but that the rapid transformation of the unstable into the stable atmospheric equilibrium seems to be precisely the deciding factor in bringing about the phenomenon.

A series of papers by Richarz (**51**) and Stuchtey (**52**) deal with the broader aspects of the Brocken specter. Richarz gives an explanation for the bright fringes on the shadow of the balloon car, which have been much commented on of late, that is of general application for all the forms of the so-called Brocken specter. His explanation is equivalent to saying that it is only when the line of sight coincides with the direction of the incident solar ray reflected by a cloud droplet that other drops do not interrupt the reflected ray. Thus there is a maximum intensity of the total light reflected by a cloud surface, along that direction which coincides with that of the incident ray-bundle, independently of the positions of the cloud surface with reference to the direction of the incident rays. He points out, further, that if his explanation is correct, then the intensity-maximum about the car's shadow must be visible at times when lack of uniformity in size of the fog particles would prevent the formation of refraction rings. Richarz broadens his theory to include numerous cases where certain intensity-maxima have been seen without refraction phenomena, and treats conditions where needles, foliage, straws, etc., play the rôle of the fog particles. Stuchtey considers observations by himself and others which are explained by Richarz's amplified theory, and finally discusses experiments imitating a car shadow falling upon a wheat field, using a system of many parallel threads and an arc lamp 8 meters distant therefrom. In this way, and at Richarz's suggestion, he has verified experimentally the latter's theory.

Wigand and Schwab (**53**) object to Wegener's explanation of the pseudhelion as due to reflection from the horizontal basal planes of floating ice tablets; and point out that in their own observations the ice crystals had the spicular form whence it follows that the pseudhelion may be due also to reflection from horizontal prismatic faces.

Simpson (**54**) reports observations by himself in the Antarctic which seem to clearly demonstrate the presence in the atmosphere of liquid water at much lower temperatures than is generally supposed possible, and this leads him to doubt that ice spicules can cause the more intensive refraction phenomena of the colored coronas which are usually explained in part by their aid. Simpson points out in support of this view that the halos produced by cirrus are usually the very ones showing the most brilliant colors. He shows, however, by more careful investigation of the process, that the first assumption of a helter-skelter arrangement of the ice spicules would produce an impure mixture of colors which could not give more than a weak suggestion of color to the cloud. He points out that a quantity of spicules are always floating in a position that brings their longer axes horizontal which would produce an effect contradictory to our experience, that the halos are more brilliant above and below than they are on either side the luminary. On the other hand, if water drops are the refracting elements, then high cirrus are the most favorable prerequisites for the production of specially brilliant halos, in so far as the absence of various sized dust particles and of vortex motions is specially favorable to the wide-spread formation of very small drops of uniform diameter. Interesting as this question is for meteorology, we can not do more than mention Simpson's very interesting section devoted to iridescent clouds, which he also explains by the aid of refracting water droplets.

Unfortunately I have not space sufficient to properly notice Möbius's (**55**) very valuable work on the theory of the rainbow, based upon Kirchhoff's strict conception of the Huyghens-Fresnel principle. Filehne's (**56**) work on the apparent form of the heavens, using relative numbers obtained by Reimann's method for the apparent diameter of the sun between altitudes 0° and 55°, finds the sky to have the shape of a half-ellipsoid of rotation whose major axis is the diameter of the horizon and one-half minor axis is the distance to the zenith. The latter element is subject to slight corrections resulting from the depression of the horizon.

In conclusion comes a work by Charles-Gallisot. The phenomenon of twinkling is very important in estimating the order of brilliancy of the stars, therefore our author investigated scintillation photometrically, using an artificial light of different colors to determine the influence of brightness, duration of light emission, and the frequency of the individual flashes upon the observed brilliancy. He finds, from the work of various observers, that the effect of scintillation upon estimates of brilliancy, is to increase the intensity of the blue ray as compared with the red ray, directly as the photometric strength of the luminous body. He believes to have found the same to be true in the case of star-brilliancy observations, and that his preliminary results throw some light on G. Müller's (**57**) photometric investigations which showed that

the increasing photoabsorption as stars approach the horizon affects the blue stars less than it does the red stars.

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PRESSURE-DIFFERENCES IN THE FREE AIR.

By W. N. SHAW.

[Translation of Abstract by J. Hann in Met. Ztschr., März 1914, 31. Jhrg., p. 143.]

If we represent by p and $p+\Delta p$ the air pressure at two places having the same level, and seek the variations of the pressure-differences with increase of altitude (dh) in the verticals of those places, we obtain the expressions

$$dp=-\rho dh,$$
$$d(p+\Delta p)=-(\rho+\Delta\rho)dh$$

whence

$$d(\Delta p)=-\Delta\rho dh.$$

Substituting for $\Delta\rho$ (variation of density with pressure and temperature) its equivalent expression, we obtain:

$$\frac{d\Delta p}{dh}=\frac{p}{RT}\left(\frac{dt}{T}-\frac{dp}{p}\right),$$

where $R=29.3$.

The change of the pressure-differences in the verticals between the two places, for one unit in variation of altitude is represented by

$$\frac{p}{RT}\left(\frac{dt}{T}-\frac{dp}{p}\right)=0.0341\frac{p}{T}\left(\frac{dt}{T}-\frac{dp}{p}\right).$$

Shaw would ascribe a special significance, for atmospheric dynamics, to the above difference in parentheses. The change of the wind force with altitude certainly depends on the changes of the pressure-differences between areas of high pressure and areas of low pressure.

Let us first consider the increase with altitude, of the difference of air pressure. We know that in the stratosphere it is cooler over a high pressure area $(p+dp)$ than over a low pressure area; therefore dp and dt have opposite signs and consequently $\Delta t/T$ and $\Delta p/p$, respectively, increase numerically but in opposite directions, and for this reason the pressure-differences decrease very rapidly with altitude in the stratosphere itself. This is true in general at those levels which are tropospheric over a station with high pressure, and stratospheric over another with low pressure. But in the troposphere the air in an area of high pressure is warmer than in one of low pressure, and therefore in this case dt and dp have the same sign. Between the earth's surface and 9 km. T changes from about 280° to 220°, while for p the change may be assumed to be from about 760 mm. to 230 mm. Thereore the temperature decreases much more slowly than the pressure ($T'/T=0.78$; $p'/p=0.30$). Hence, between the earth's surface and 9 km. dp/p varies considerably while dt/T remains relatively more stable. Therefore, between 9 km. and the earth's surface the difference $(dt/T-dp/p)$ may become zero at any point, and this difference may be positive in the lower portion and negative in the upper portion. Hence, in the troposphere the effect of temperature differences will be opposed to that of the pressure-differences instead of strengthening the latter as in the stratosphere.

The second factor p/T varies between $2\frac{3}{4}$ and 1, (760/273 and 230/230 at 9 km.); hence it follows that in the greater part of the troposphere the effect of the vertical changes on the difference of air pressure is undoubtedly very trifling, since dt/T and dp/p have the same sign, except sometimes at the lowest altitudes in areas of high pressure with cold at the earth's surface.

In summing up, we may say: In the stratosphere the temperature in a vertical direction is nearly uniform; in an area of high pressure the temperature is cooler than in an area of low pressure, but in the region directly under the bounding surface of the troposphere a change occurs and in the troposphere itself the high pressure area is warmer than the low pressure area except occasionally in the lowest kilometer. The effect on the differences of air pressure is: In the stratosphere even to the lowest limit the pressure-difference increases downward rapidly to a maximum; from this level up to about 1 km. from the surface of the earth through an interval of 8 km. the variations are capricious and with opposite signs and the total effect comparatively small.

Cave has discovered that at the very beginning of the stratosphere the wind force reaches a maximum, and that in this layer itself a more or less rapid decrease in wind force takes place.

Shaw has further computed that in the stratosphere the difference of air pressure diminishes more rapidly than the pressure, somewhat in the ratio of 24/16 or 3/2. The temperature is constant, and consequently the force of the wind diminishes at the rate of 9 per cent for each kilometer of altitude.

According to Shaw the above stated ratios of pressure and temperature in the stratosphere determine its predominating influence on the dynamics of the surface layers, although it constitutes only one-fourth of the atmosphere. In the stratosphere pressure-differences form with comparative rapidity whereas in the troposphere the changes are very capricious and contradictory, for which reason the influence of the layers between 1 and 9 km. is comparatively insignificant.

SECTION II.—GENERAL METEOROLOGY.

PERIOD OF SAFE PLANT GROWTH IN MARYLAND AND DELAWARE.

By OLIVER L. FASSIG, Professor of Meteorology.

[Dated Weather Bureau, Baltimore, Md., Apr. 18, 1914.]

It is customary to establish the average period of safe plant growth for a locality by determining the average dates of the last killing frost in spring and the first killing frost in fall. When a temperature of 32° F. or below occurs without the occurrence of frost during a critical period after plant activity has begun in the spring, or in the early fall before the crops have all been gathered, the date of occurrence of the last and first temperature of 32°, respectively, is substituted in place of a killing frost in determining the average dates of the last and first frosts. The occurrence of frost does not generally coincide with the occurrence of a temperature of 32°, owing to the custom of exposing the thermometer in a shelter several feet above the ground. The difference between the temperature upon the ground and the temperature within the shelter, about 5 feet above the ground, may be as much as 10°, the amount of variation depending upon the topography and the weather conditions. As a rule [on cloudless nights] the temperature at the ground is distinctly lower during the night hours than the temperature in the shelter; this condition may be reversed, however. Since the intervals based on the last and first occurrence of frost, and those based on the last and first occurrence of a temperature of 32° F., are not of equal length, the usual method of calculating the frostless period from records made up by combining both kinds of observations (instrumental and phenological) is obviously open to criticism. The use of an occasional freezing temperature to complete a long record of observed frosts is not objectionable, but a frequent substitution should not be resorted to.

In order to learn the extent of the difference in the length of the frostless period, or the difference in the length of the period of safe plant growth as determined by means of the two methods described, two distinct series of observations were tabulated and compared for all stations in Maryland and Delaware having a record covering a period of 10 years or more. Fortunately we have in these States a large number of carefully made observations extending over periods varying from 10 to 43 years. The average length of these records is 20 years, confined mostly to the period 1890–1913. The tabulated results of a study of these observations show the following facts of observation and of calculation for each of fifty-two stations in Maryland and Delaware:

1. The elevation of the station above sea level.
2. The length of the period of temperature observations.
3. The average date of the last killing frost in spring.
4. The average date of the first killing frost in fall.
5. The average length of the intervening period.
6. The average date of the last temperature of 32° in spring.
7. The average date of the first temperature of 32° in fall.
8. The average length of the intervening period.
9. The difference in the length of the two intervening periods, based respectively on frost observations and on temperature observations.
10. The earliest and latest occurrence of the last temperature of 32° in spring.
11. The average departure from the normal date of the last spring temperature of 32°.
12. The earliest and latest occurrence of the first temperature of 32° in fall.
13. The average departure from the normal date of the first temperature of 32° in fall.
14. The longest period of safe plant growth, with year of occurrence.
15. The shortest period of safe plant growth, with year of occurrence.
16. The extreme variation in the period of safe plant growth.
17. The average departure, in days, from the normal length of the period.

The tabulated material has also been charted in order to show at a glance the geographical relations of the values determined. A comparison of the figures and charts showing the length of the two growing seasons suggests the advisability of adopting a uniform method of determining the period of safe plant growth, and appears to demonstrate the superiority of the method based upon the last and first occurrence of a fixed temperature, for example 32° F., over the usual method of observing and recording the dates of the last and first killing frosts in spring and fall, respectively.

Some of the reasons which may be advanced in favor of the method of determining the period from the temperature records are the following:

1. The temperature is observed and recorded regularly each day, and the record is therefore complete for the entire season.
2. Frost records are apt to be incomplete unless they occur at critical periods in plant growth. This failure to record frosts is particularly noticeable in records of spring frosts; stations having excellent fall records have often a very defective record of spring frosts. Frosts occurring after a long period of warm weather, as in summer or early fall, are likely to be more conspicuous events than the last of a series of many frosts occurring throughout the winter and early spring.
3. In recording frosts there is always a variable personal factor, opinions differing as to the extent and severity of the frost, resulting in the same frost being designated as "heavy" or "killing." In recording temperatures, on the other hand, this personal factor is practically eliminated.
4. There is a fairly fixed and uniform relation existing between the temperature in the shelter and the occurrence of a killing frost in any given locality, and this factor can be readily determined from a comparatively short series of observations.
5. For reasons stated above a reliable "frostless period" may be established for a given locality from a shorter series of observations by the use of a temperature record than by the use of a frost record.

The Maryland and Delaware records, covering an average period of 20 years at 50 stations, show that the frostless period based on the observations of a temperature of 32°F. is about 10 days longer than the period based on the occurrence of killing frosts. This relation holds good in general for stations in open, level places, but apparently does not hold for stations in the mountain districts, where the period based on the occurrence of frosts is longer than that determined from a record of freezing temperatures in a shelter 5 feet above the ground.

The longer "frostless period" in the mountains is explained by the fact that the last frost in spring and the first in fall occur late in the spring and early in the fall, at times when the ground is warmer than the air above it. This explanation is supported by the fact that the average temperature at the time of occurrence of killing frosts at the stations in question is found to have been between 28°F. and 30°F., while the average temperature at the time of occurrence of killing frosts at the level lowland stations is found to have been approximately 32° F.

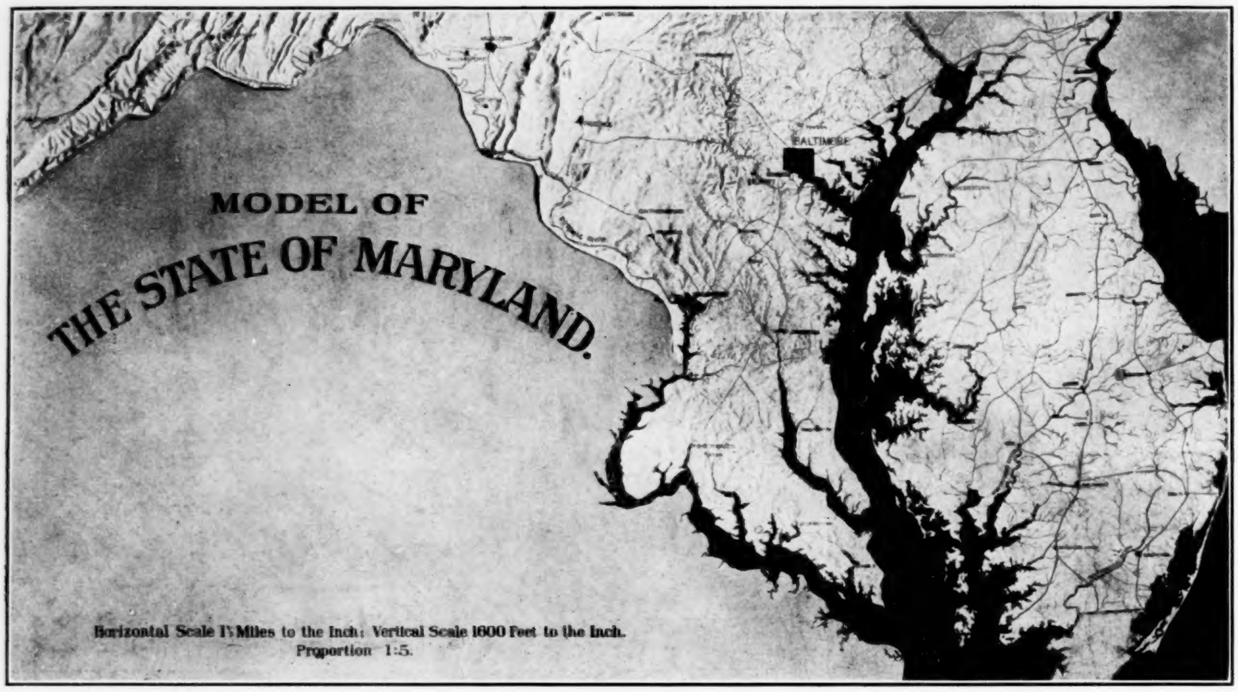

FIG. 1.—Relief map of the States of Maryland and Delaware. (Courtesy of Maryland Geological Survey.)

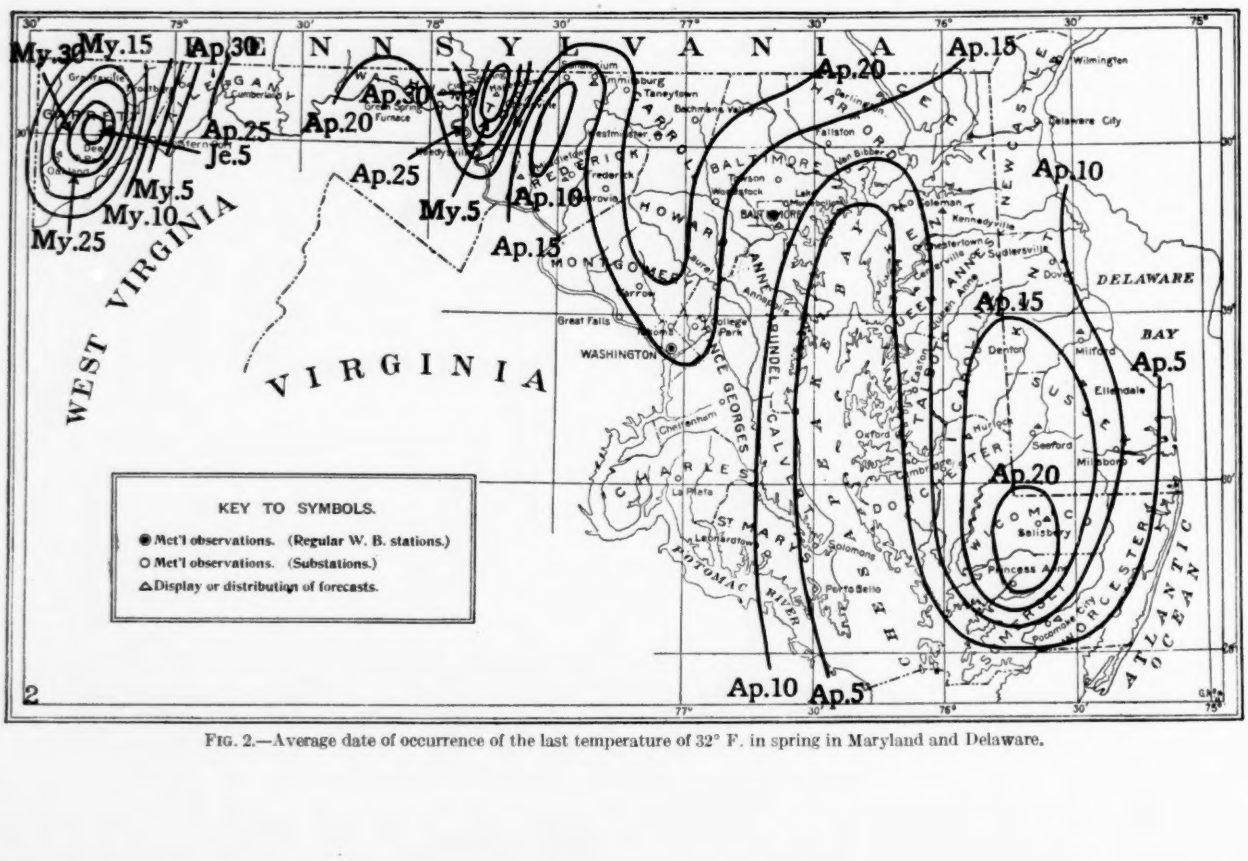

FIG. 2.—Average date of occurrence of the last temperature of 32° F. in spring in Maryland and Delaware.

Laurel is the one exception to the general rule that in the level lowlands the period based on a temperature of 32°F. is longer than the period based on frost observations, and the difference here is small, namely, two days. It is noteworthy that Laurel is the one station at which the thermometer shelter is 6 inches above the ground, while at all other stations the shelter is placed at an elevation of about 5 feet above the ground.

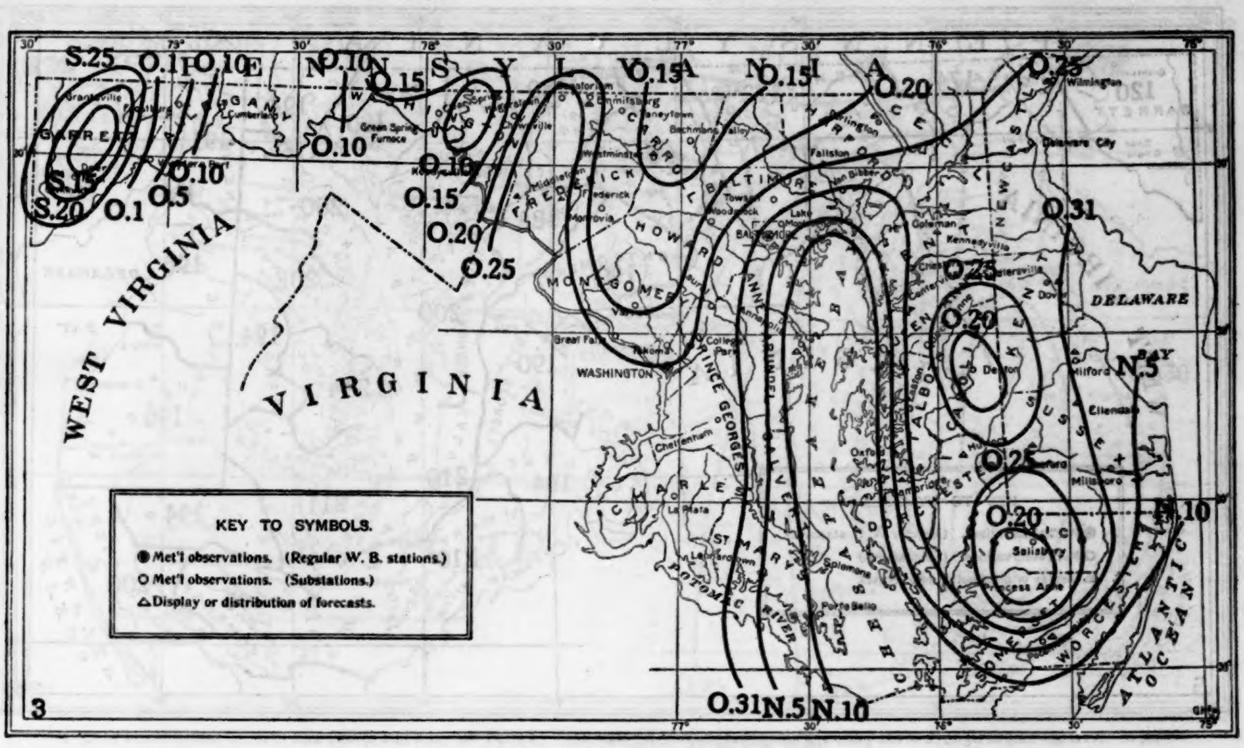

FIG. 3.—Average date of occurrence of the first temperature of 32° F. in fall in Maryland and Delaware.

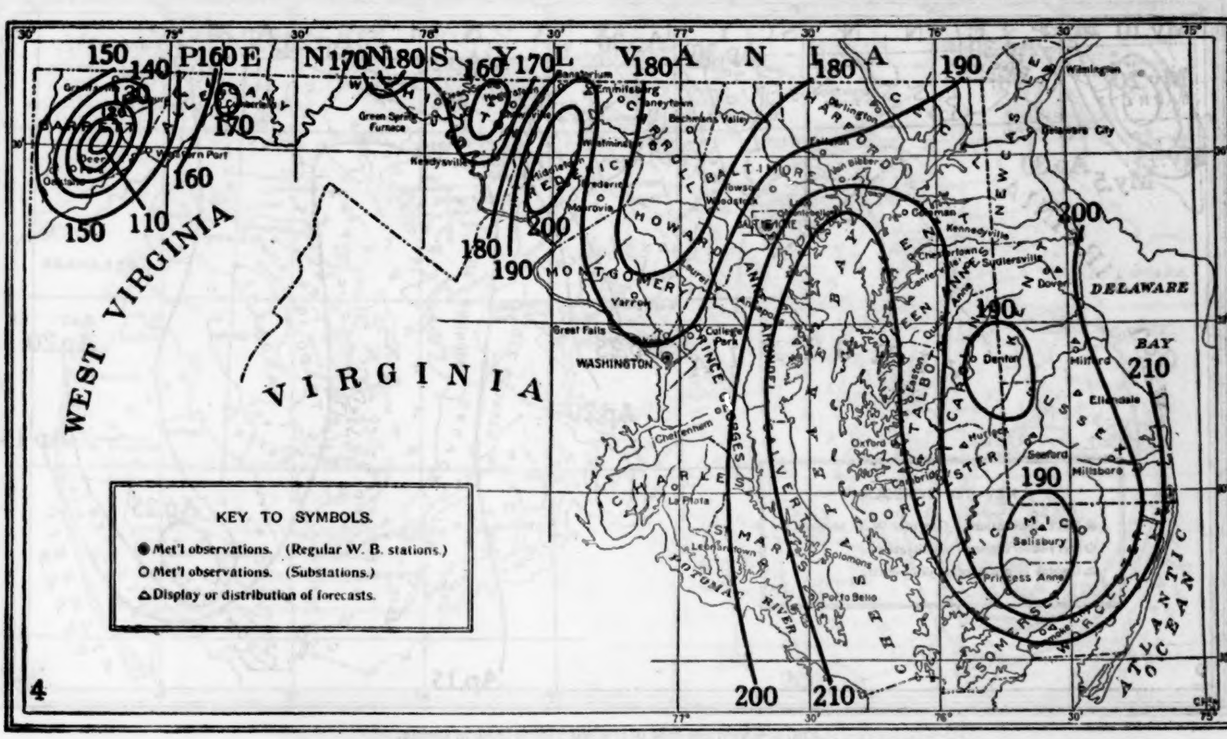

FIG. 4.—Average length of the period of safe plant growth. (Based on number of days between last spring and first fall temperature of 32° F.)

The necessity for charting these two systems of observations separately is apparent, and I believe that the method based on a record of the last temperature of 32° F. in spring and the first temperature of 32° F. in fall is the better method. The formation of frost depends not only upon the occurrence of a temperature of 32° F. or lower, but also upon the relative humidity of the air at the time and place of formation; the temperature may fall consid-

erably below the freezing point for water without the occurrence of frost in a dry atmosphere. The injury to plants is probably as great in one case as in the other, yet less periods (figs. 4 and 8), and of lines showing the beginning and ending of the periods (figs. 2, 3, 6, and 7); but the charts based upon the temperature records (figs. 2,

FIG. 5.—Average length in days of the period of safe plant growth, by counties. (Period between last spring and first fall temperature of 32° F.)

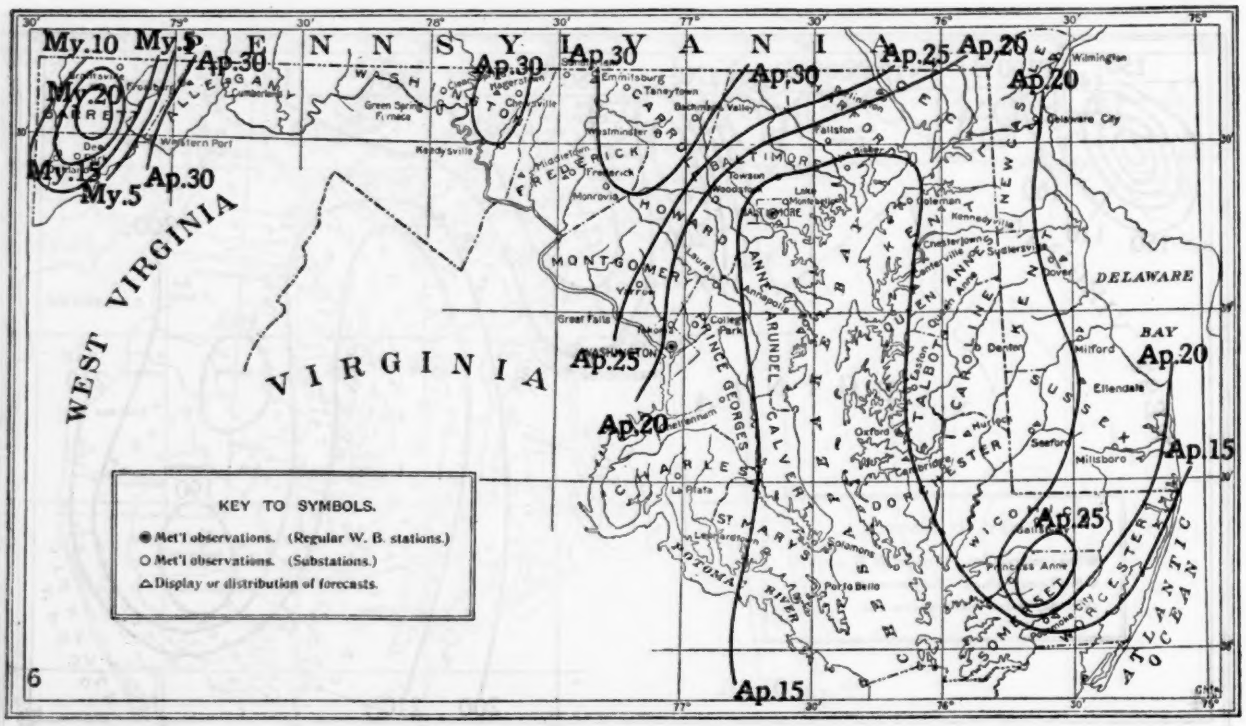

FIG. 6.—Average date of the last killing frost in spring.

the absence of frost may give the impression that no injury has resulted.

A comparison of the charted results of the two methods shows a similar configuration of the lines of equal frost- 3, and 4) show greater detail owing to the use of a greater number of stations and a greater average length of the periods of observation permitted by the temperature method.

Nearly all of the temperature observations used in the construction of the accompanying charts were made under similar methods of exposure of thermometers, viz, in like Baltimore and Washington where the thermometers are exposed upon the roofs of buildings at elevations of 100 feet or more above the ground.

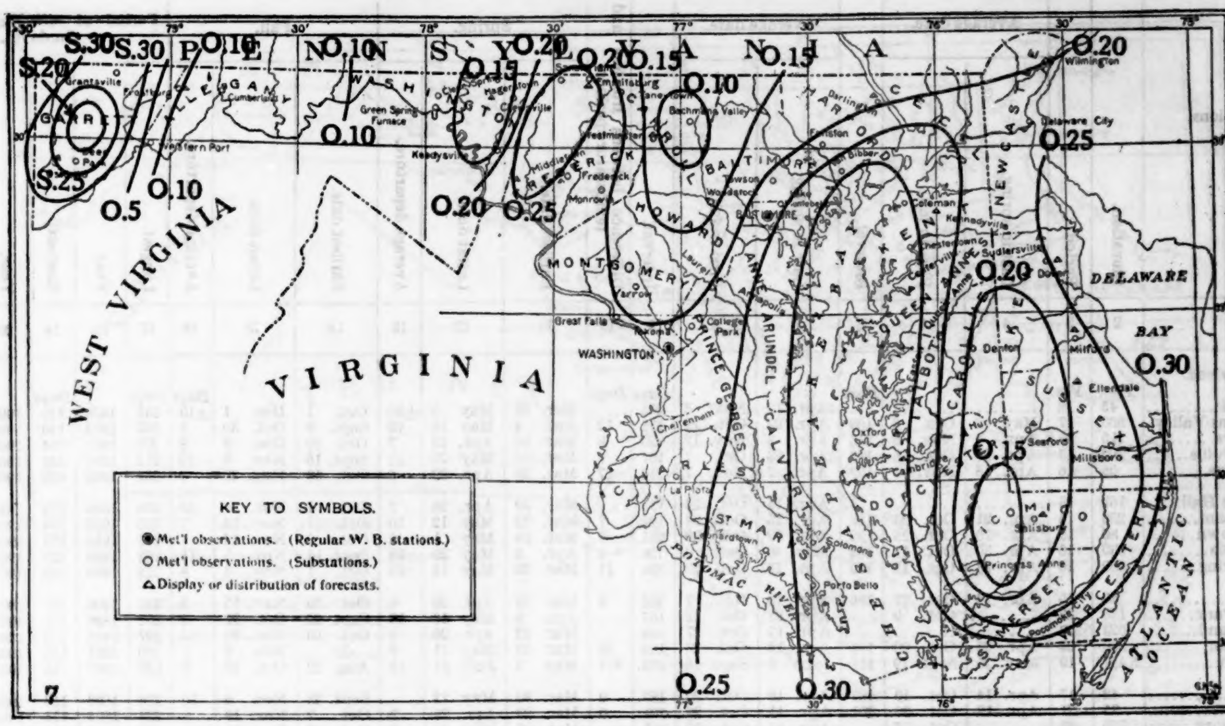

FIG. 7.—Average date of the first killing frost in fall.

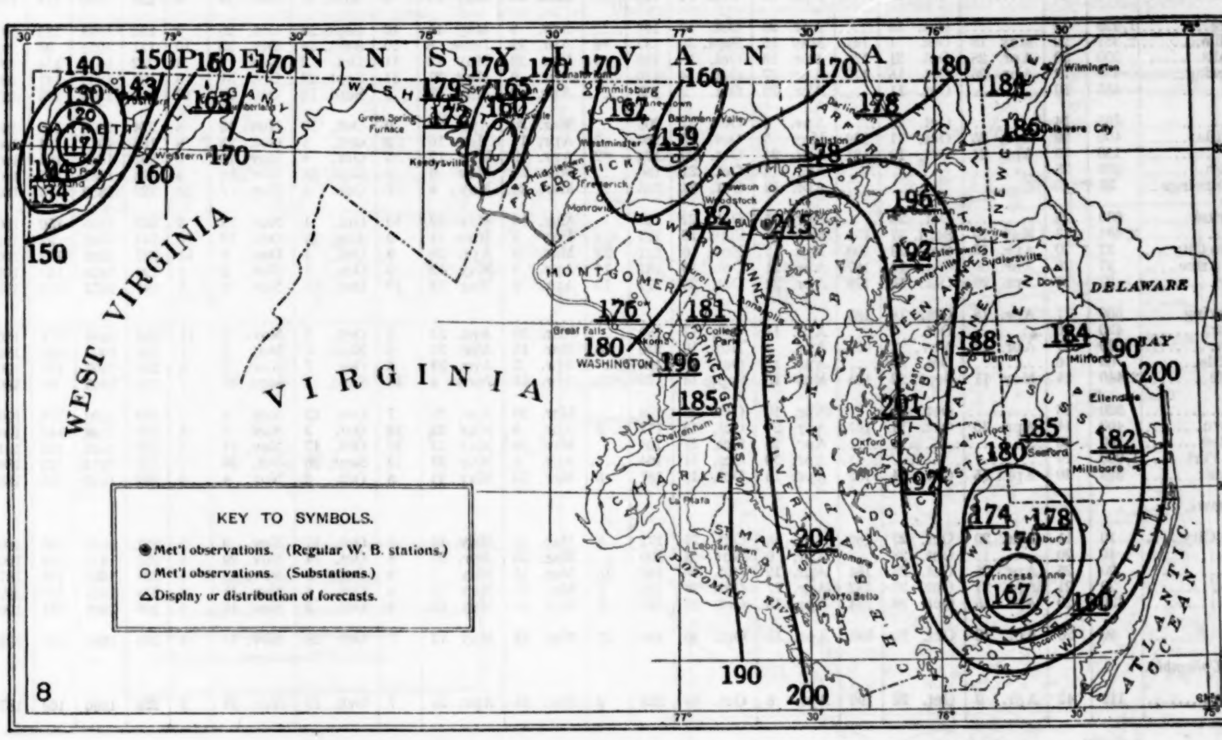

FIG. 8.—Average length, in days, of the frostless period. Local intervals are underscored.

standard Weather Bureau shelters about 5 feet above the ground in country districts or in open places in small towns. Proper allowance must be made for temperatures observed under conditions which differ widely from the usual methods of exposure, such as those of large cities

The charts show quantitatively what has long been recognized in a general way, viz, the great influence of Chesapeake Bay in lengthening the period of safe plant growth in Maryland. This fact is conspicuous in all the charts.

TABLE 1.—*The period of safe plant growth in Maryland and Delaware.*

	Stations.	Elevation.	Period.	Killing frost. Average date. Last in spring.	Killing frost. Average date. First in fall.	Killing frost. Interval.	Temperature of 32° F. Average date. Last in spring.	Temperature of 32° F. Average date. First in fall.	Temperature of 32° F. Interval.	Difference between frostless and temperature periods.	Spring. Earliest date.	Spring. Latest date.	Spring. Average departure.	Fall. Earliest date.	Fall. Latest date.	Fall. Average departure.	Period of safe plant growth (in days). Longest.	Year.	Shortest.	Year.	Extreme range.	Average departure from normal safe growing period.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Maryland.	*Feet.*	*Yrs.*			*Days*			*Days*	*Days*						*Days*	*Days*		*Days*		*Dys*	*Dys*
1	Annapolis	45	18				Apr. 12	Nov. 3	205		Mar. 29	May 5	±10	Oct. 1	Dec. 1	±10	241	1896	170	1906	71	±14
2	Bachmans Valley	860	17	May 2	Oct. 8	159	Apr. 24	Oct. 12	171	12	Apr. 4	May 16	10	Sept. 9	Oct. 30	8	197	1902	140	1904	57	13
3	Baltimore	115	43	Apr. 4	Nov. 5	215	Apr. 3	Nov. 12	223	9	Mar. 16	Apr. 22	7	Oct. 29	Dec. 6	8	278	1871	194	1904	84	12
4	Boetcherville	780	13	Apr. 26	Oct. 6	163	Apr. 23	Oct. 7	167	4	Mar. 30	May 21	11	Sept. 15	Nov. 9	10	212	1894	139	1905	73	15
5	Cambridge	25	16	Apr. 18	Nov. 1	197	Apr. 7	Nov. 7	214	17	Mar. 20	Apr. 20	6	Oct. 13	Nov. 29	9	254	1902	190	1907	64	15
6	Charlotte Hall	167	13				Apr. 14	Oct. 24	195		Mar. 30	Apr. 28	7	Oct. 1	Nov. 14	10	209	1896	172	1898	37	14
7	Cheltenham	230	14	Apr. 21	Oct. 23	185	Apr. 15	Oct. 24	192	7	Mar. 22	May 12	10	Oct. 11	Nov. 14	7	222	1910	153	1906	69	16
8	Chestertown	80	19	Apr. 16	Oct. 25	192	Apr. 12	Oct. 30	201	9	Mar. 19	May 1	8	Oct. 5	Nov. 14	7	225	1910	171	1907	54	11
9	Chewsville	530	16	Apr. 30	Oct. 12	165	May 6	Oct. 9	156	* 9	Apr. 5	May 29	12	Sept. 14	Nov. 1	11	202	1898	125	1905	77	18
10	Clear Spring	650	16	Apr. 23	Oct. 19	179	Apr. 15	Oct. 22	190	11	Mar. 20	May 12	10	Oct. 1	Nov. 3	8	218	1910	162	1907	56	16
11	Coleman	80	16	Apr. 14	Oct. 27	196	Apr. 10	Nov. 1	205	9	Mar. 29	Apr. 20	6	Oct. 20	Nov. 15	5	226	1906	191	1904	35	8
12	College Park	170	22		Oct. 9		Apr. 28	Oct. 12	167		Apr. 9	May 16	10	Sept. 22	Oct. 31	8	202	1898	131	1904	71	13
13	Cumberland	623	27				Apr. 12	Oct. 27	198		Mar. 22	Apr. 26	6	Oct. 10	Nov. 24	10	227	1886	172	1888	55	14
14	Darlington	300	22	Apr. 25	Oct. 20	178	Apr. 18	Oct. 23	188	10	Mar. 30	May 11	9	...do....	Nov. 6	6	210	1901	154	1906	56	10
15	Deer Park	2,457	19	May 25	Sept. 19	117	June 5	Sept. 15	103	*14	May 3	July 31	19	Aug. 22	Oct. 10	9	135	1906	48	1909	87	20
16	Denton	42	17	Apr. 14	Oct. 19	187	Apr. 16	Oct. 20	187	0	Mar. 30	May 12		Sept. 23	Nov. 6	10	216	1893	153	1904	63	14
17	Easton	35	21	Apr. 12	Oct. 30	201	Apr. 11	Oct. 29	201	0	Mar. 22	Apr. 28	7	Oct. 2	Nov. 19	9	223	1894	174	1899	49	12
18	Emmitsburg	720	33		Oct. 27		Apr. 11	Oct. 29	201		Mar. 25	May 10	8	Oct. 7	Nov. 16	9	232	1888	155	1906	77	14
19	Fallston	450	21	Apr. 21	Oct. 16	178	Apr. 15	Oct. 22	189	11	Mar. 19	May 12	10	Oct. 3	Nov. 14	8	224	1910	163	1907	61	12
20	Frederick	275	25		Oct. 22		Apr. 11	Oct. 24	196		Mar. 18	May 12	9	Sept. 23	Nov. 24	9	236	1890	154	1904	82	15
21	Frostburg	1,929	12		Oct. 10		Apr. 26	Oct. 10	167		Apr. 9	May 11	10	Sept. 23	Oct. 25	9	192	1898	135	1913	57	12
22	Grantsville	2,351	20	May 13	Oct. 1	141	May 15	Sept. 30	137	*4	Apr. 22	June 8	10	Sept. 14	Oct. 25	10	171	1911	95	1913	76	18
23	Great Falls	200	30	Apr. 28	Oct. 21	176	Apr. 16	Oct. 18	185	9	Mar. 23	May 12	11	Oct. 2	Nov. 7	8	222	1910	154	1906	68	15
24	Green Spring	450	19	Apr. 26	Oct. 15	172	Apr. 27	Oct. 14	170	*2	Apr. 9	May 21	11	Sept. 23	Oct. 31	8	196	1898	147	1907	49	12
25	Hancock	455	10		Oct. 11		Apr. 23	Oct. 3	163		Apr. 9	May 12	9	Sept. 15	Oct. 28	10	202	1898	143	1895	59	13
26	Jewell	165	14		Oct. 25		Apr. 9	Oct. 31	205		Mar. 20	Apr. 28	9	Oct. 10	Nov. 13	8	224	1902	183	1898	41	12
27	Keedysville	400	19	Apr. 25	Oct. 11	169	May 3	Oct. 16	166	7	Apr. 11	May 16	9	Oct. 3	Oct. 25	8	188	1912	154	1906	34	8
28	Laurel	150	19	Apr. 21	Oct. 19	181	Apr. 24	Oct. 20	179	*2	Apr. 9	May 12	8	Oct. 4	Nov. 15	7	201	1898	154	1906	47	9
29	McDonogh	500	28				Apr. 14	Oct. 27	196		Mar. 26	May 9	9	Sept. 23	Nov. 18	9	228	1881	155	1904	73	12
30	Mardela Springs	25	12				Apr. 12	Oct. 24	195		Mar. 29	May 4	7	Oct. 3	Nov. 7	10	222	1889	175	1899	47	12
31	New Market	630	25		Oct. 20		Apr. 15	Oct. 22	190		Mar. 16	May 12	10	Oct. 1	Nov. 13	9	227	1910	150	1907	77	14
32	Oakland	2,461	13	May 19	Sept. 27	131	May 21	Sept. 18	117	*14	May 3	June 11	9	Aug. 27	Oct. 10	10	144	1893	92	1913	52	12
33	Pocomoke City	37	20	Apr. 16	Oct. 23	190	Apr. 7	Nov. 6	211	23	Mar. 18	Apr. 28	9	Oct. 1	Dec. 8	11	227	1903	192	1906	35	9
34	Princess Anne	17	20	Apr. 30	Oct. 14	167	Apr. 21	Oct. 19	181	14	Apr. 9	May 12	9	Oct. 1	Nov. 2	8	199	1910	153	1896	46	11
35	Salisbury	23	10	Apr. 23	Oct. 16	176	Apr. 24	Oct. 20	179	12	Apr. 9	May 12	10	Oct. 12	Nov. 2	6	191	1912	154	1906	37	10
36	Sandy Spring	500	17	Apr. 18	Oct. 18	183																
37	Sharpsburg	420	10		Oct. 4		Apr. 11	Oct. 17	189		Mar. 30	Apr. 22	6	Oct. 1	Nov. 9	11	212	1900	175	1895	37	13
38	Solomons	20	21	Apr. 13	Nov. 3	204	Apr. 3	Nov. 19	230	26	Mar. 16	Apr. 27	8	Nov. 5	Dec. 5	7	254	1902	203	1893	51	12
39	Sudlersville	65	16		Oct. 22		Apr. 13	Oct. 25	195		Apr. 3	Apr. 23	6	Oct. 7	Nov. 7	8	216	1903	170	1904	53	9
40	Sunnyside	2,440	11	May 11	Sept. 22	134	May 15	Sept. 14	122	*12	Apr. 18	June 9	16	Sept. 2	Sept. 25	7	152	1896	88	1902	64	17
41	Takoma	320	15		Oct. 24		Apr. 10	Oct. 25	198		Mar. 20	Apr. 21	7	Oct. 12	Nov. 9	7	223	1900	176	1905	47	11
42	Taneytown	490	14	Apr. 30	Oct. 14	167	Apr. 24	Oct. 13	172	5	Apr. 6	May 22	14	Oct. 2	Nov. 3	6	194	1898	140	1907	54	13
43	Van Bibber	100	16				Apr. 15	Oct. 27	195		Mar. 29	May 12	10	Oct. 17	Nov. 14	6	218	1900	163	1913	55	10
44	Western Port	1,000	19				Apr. 30	Oct. 11	164		Apr. 8	May 21	12	Sept. 20	Oct. 30	9	191	1912	132	1895	59	11
45	Woodstock	392	40	Apr. 15	Oct. 14	182	Apr. 15	Oct. 19	187	5	Mar. 22	May 11	8	Oct. 2	Nov. 4	9	222	1910	153	1882	69	14
	Delaware.																					
46	Delaware City	10	11	Apr. 20	Oct. 23	186	Apr. 18	Oct. 27	192	6	Mar. 22	May 11	9	Oct. 11	Nov. 9	7	221	1910	186	1908	35	14
47	Dover	40	20		Oct. 28		Apr. 9	Nov. 4	209		Mar. 20	Apr. 28	8	Oct. 14	Nov. 29	6	251	1876	183	1907	68	15
48	Milford	20	25	Apr. 25	Oct. 26	184	Apr. 12	Oct. 28	199	15	Mar. 16	May 3	8	Oct. 2	Nov. 18	9	228	1902	168	1874	60	12
49	Millsboro	20	21	Apr. 21	Oct. 20	182	Apr. 17	Oct. 24	190	8	Mar. 30	May 11	8	Oct. 4	Nov. 11	8	214	1893	154	1906	60	11
50	Newark	136	20	Apr. 15	Oct. 16	184	Apr. 15	Oct. 22	190	6	Mar. 18	May 12	9	Oct. 2	Nov. 16	9	226	1908	161	1907	65	13
51	Seaford	40	20	Apr. 18	Oct. 20	185	Apr. 13	Oct. 28	198	13	Mar. 18	May 12	7	Oct. 18	Nov. 13	8	236	1901	163	1913	73	12
	District of Columbia.																					
52	Washington	112	42	Apr. 9	Oct. 22	196	Apr. 8	Oct. 30	205	9	Mar. 18	Apr. 29	7	Oct. 10	Nov. 18	8	229	1886	169	1874	60	10

* Frostless period longer than temperature period. At all other stations the temperature period is longer than the frostless period.

The protecting influence of the mountains in the western part of Maryland (see fig. 1 for topography of the State) is also clearly shown in the greater length of the frostless period on the eastern, or leeward side, and in the contrast between conditions on the western and eastern sides of the Blue Ridge Mountains in Washington and Frederick Counties.

The period of safe plant growth along Chesapeake Bay in southern Maryland, is longer by nearly 100 days than the period in Garrett County in the mountains of western Maryland.

Taking the average for a long series of years, a temperature of 32° F. or below disappears in spring along the shores of Chesapeake Bay and along the Atlantic coast

about April 5, to reappear in the fall about November 10 or 12, showing a period of safe plant growth of about 210 days. These figures apply, however, only to localities near the shore. The length of the period diminishes rather rapidly with increasing distance from the water's edge. This protecting influence of the Bay is strikingly brought out in figure 4, showing the variations in the length of the frostless period on what is known as the "Peninsula," including Delaware and the district in Maryland between the Atlantic Ocean and Chesapeake Bay. In the central portions of the Peninsula, farthest away from the Bay and the ocean, regions in which nocturnal radiation is more active than in the immediate vicinity of large bodies of water, freezing temperatures do not usually disappear in the spring until April 15 to 20, and reappear in the fall about October 20 to 25, de-

FIG. 9.—Difference in days between the periods of safe plant growth as based on frost data and on temperature data. Plain figures indicate temperature period greater than frost period. Underscored figures indicate frost period greater than temperature period.

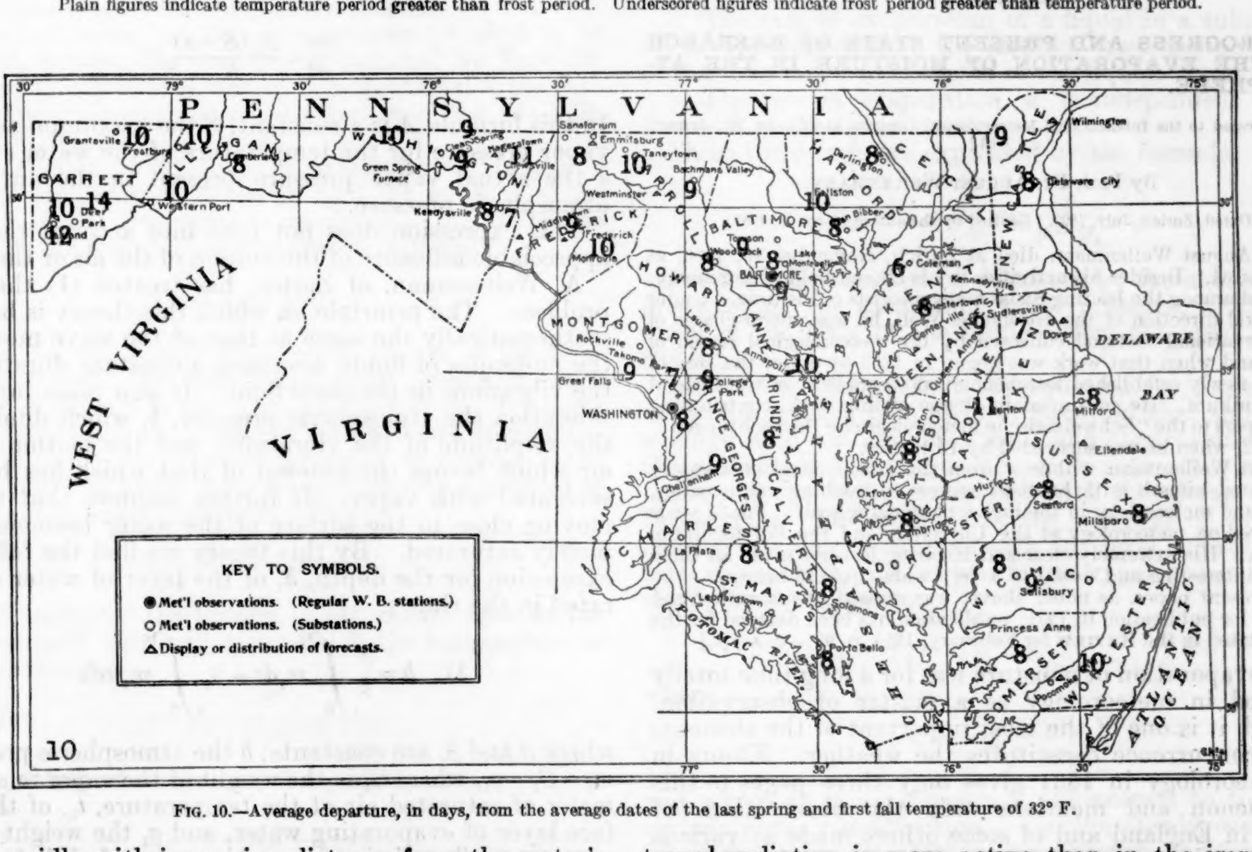

FIG. 10.—Average departure, in days, from the average dates of the last spring and first fall temperature of 32° F.

creasing the period of safe plant growth from 210 days near the shores to 190 days at distances only 20 to 25 miles inland, a difference of 20 days. Differences in soils are doubtless in part responsible for these variations.

In the mountain districts of the Blue Ridge (see fig. 1) we have a striking example of the protecting influence of a mountain range stretching across the path of the prevailing westerly winds. On the western or windward side of the Blue Ridge, in the lower levels of the Cumberland Valley, the frost period extends into the first week of May and reappears in the fall in the first decade of October, showing a period of safe plant growth of about 160 days. On the eastern or protected side of the Ridge the period is lengthened to 190 days, and even 200 days, the freezing temperatures disappearing about April 15 and reappearing in the third decade of October. In the mountain districts the variations in the length of the season are to some extent due to cold-air drainage during clear and calm nights and can not be altogether attributed to the protecting influence of the mountains against the cold westerly winds.

In the most western county of Maryland we find another factor entering into the length of the period of safe plant growth, namely, that of elevation, as shown by figure 1. The general level of Garrett County is not far from 2,500 feet above sea level, with peaks rising to 3,000 feet. Here we have a very decided shortening of the period, injurious frosts extending into the early days of June and appearing again about the middle of September, showing a period of safe plant growth of but little more than 100 days in the areas exposed to intense nocturnal radiation and to extensive air drainage.

THE PROGRESS AND PRESENT STATE OF RESEARCH ON THE EVAPORATION OF MOISTURE IN THE ATMOSPHERE.

[Communicated to the International Meteorological Congress at Chicago, Ill., August, 1893.]

By Prof. Dr. AUGUST WEILENMANN.

[Dated, Zurich, July, 1893. Revised by the author March 24, 1901.]

[Prof. August Weilenmann died at Zurich, November 10, 1906, at the age of 64. Besides his activities in his chosen field of astronomy, he ranked among the leading Swiss meteorologists of his time. Under the general direction of the astronomer Wolf, he was put in charge of the observational material collected by the meteorological réseau of Switzerland when that work was begun in 1863-64 under the care of the then newly established astrononomical observatory of the Federal Polytechnikum. He continued in charge of this work, contributing many papers to the "Schweizerische meteorologische Beobachtungen," until 1872, when he was succeeded by Billwiller.

In 1873 Weilenmann withdrew from the astronomical observatory and devoted himself with brilliant success to teaching mathematics, physics, and meteorology in the higher cantonal schools. For 30 years he lectured on meteorology at the University and the Polytecnikum in Zurich. His extremely clear and inspiring lectures made all these subjects interesting and useful to a very wide circle of hearers.

The present paper, as noted above, was revised by its author and prepared for publication in 1901; publication has been delayed for the reasons stated in the REVIEW for February, 1914, p. 93.—C. A., jr.]

The evaporation of moisture was for a long time totally neglected in meteorology as a matter of observation, although it is one of the most important of the elements whose concurrence constitutes the weather. Kämtz in his Meteorology in 1831 gives only three pages to this phenomenon and mentions only the observations of Dalton in England and of some others made at various places in France and Holland. Schübler in his Meteorology of 1831 gives his own results at Tübingen. Schmid in his great treatise of 1860 knows no other observations than those already mentioned, by Kämtz and Schübler, and on page 600 he says: "The total result of these observations on evaporation simply leads to the conclusion that it is absolutely impossible to determine even approximately the quantity of moisture that passes from the surface of the earth into the atmosphere during a given time and at a given place." Although this conclusion may be true to a certain degree, and although the observations made under diverse conditions may not be absolutely comparable and may differ in total amount from the quantities that evaporate from the ocean or the open surface of the land, still the researches and experiments on this subject are of great importance and furnish a useful factor wherewith to characterize the climate of a given place. Moreover, the observations organized by Wild in Russia and by Hann in Austria-Hungary show that the results obtained with similar instruments similarly exposed are comparable. Therefore, in spite of the discouraging words of Schmid, the observations of the evaporation of moisture have not been abandoned, but rather have been greatly increased since 1860. The space conceded to this present report does not allow me to communicate all [1] that has been accomplished within the past 50 years (1843-1892), but it may be sufficient to give the most important results. I shall divide this paper into two portions: Theory and Instruments and observations.

THEORY.

The well-known physicist Dalton was among the first to endeavor to state the connection between evaporation and the elements on which it depends. He gives the following formula for the rate of evaporation:

$$\frac{dv}{dt}=\frac{A\ (S-s)}{b}$$

In this formula A is a constant, S the maximum aqueous vapor pressure for the temperature of the water surface, s the actual vapor pressure present in the air, b the atmospheric pressure.

This expression does not take into account the very appreciable influence of the motion of the air or the wind.

A. Weilenmann, of Zurich, has treated (1) the same problem. The principle on which this theory is based is mathematically the same as that of the wave motion of the molecules of fluids, assuming a constant duration for the vibrations in the same fluid. It also takes into consideration the atmospheric pressure, b, which diminishes the amplitude of the vibrations, and the motion of the air which favors the renewal of that which has become saturated with vapor. It further assumes that the air moving close to the surface of the water becomes completely saturated. By this theory we find the following expression for the depth, h, of the layer of water evaporated in the time z.

$$1)\quad h=\frac{\beta}{b}\int_0^z m_1 dz+\beta_1\int_0^z m_1 w dz$$

where β and β_1 are constants; b the atmospheric pressure; $m_1=G_1-g_1$, where G_1 is the weight of the vapor in a cubic meter of saturated air at the temperature, t_1, of the surface layer of evaporating water, and g_1 the weight of the vapor actually existing in a cubic meter of air before con-

[1] See "An annotated bibliography of evaporation," MONTHLY WEATHER REVIEW, June, 1908, to June, 1909. Also reprinted.—EDITOR.

tact with the layer of water; w the velocity of the wind. If a psychrometer is observed in the vicinity of the evaporometer, we can express m_1 in terms of the temperatures, t and t_1, of the dry- and wet-bulb thermometers, and we thus find

$$2)\quad h=\gamma\int_0^z\frac{t-t_1}{T}dz+\gamma_1 b\int_0^z\frac{t-t_1}{T}wdz$$

where $\gamma=\frac{\beta}{b}$ and $\gamma_1=\frac{\beta_1}{b}$ are constants and $T=273°+t$, is the absolute temperature in centigrade degrees.

If T_m is the mean value of T we shall, with sufficient approximation, have

$$3)\quad h=\frac{\gamma}{T_m}\int_0^z(t-t_1)dz+\frac{\gamma_1 b}{T_m}\int_0^z(t-t_1)wdz$$

and the rate of evaporation becomes:

$$4)\quad u=\frac{dh}{dz}=\frac{\gamma}{T_m}(t-t_1)+\frac{\gamma_1 b}{T_m}(t-t_1)w.$$

For any given station these expressions become:

$$5)\quad h=\varepsilon\int_0^z(t-t_1)dz+\varepsilon_1\int_0^z(t-t_1)wdz$$

$$6)\quad u=\varepsilon(t-t_1)+\varepsilon_1(t-t_1)w$$

where ε and ε_1 are constants for that station.

These equations, assuming the velocity of wind to be constant, express the law first enunciated by Tate (2) that the velocity of evaporation is proportional to the psychrometric difference, or the depression of the wet-bulb below the dry-bulb.

But as most publications of climatological data give only the temperature of the air and the aqueous vapor pressure, it is necessary to recalculate the difference $(t-t_1)$ by the ordinary psychrometric formula:

$$7)\quad S_1-s=kb(t-t_1)$$

where S_1 is the tension of saturated vapor at the temperature t_1 of the wet-bulb; s the actual tension of vapor present in the air at the temperature t of the dry-bulb; $k=0.00066$, when the pressures are expressed in millimeters of mercury and the temperatures in degrees centigrade. For any given place b and k may be combined as being approximately constant. Let

$$8)\quad S_1=S-\alpha(t-t_1)$$

where S indicates the tension of saturated vapor at the temperature t; then will α vary with the temperature in a definite manner.

Putting $$\eta=\frac{273}{(\alpha+kb)(273+t)}$$

and the deficit of saturation, d, equals S_1-s we have:

$$9)\quad u=\theta\eta d+\theta_1\eta wd$$

$$10)\quad h=\theta\int_0^z\eta ddz+\theta_1\int_0^z\eta wddz$$

θ and θ_1 are constant for the same station, but $\theta_1=\theta_2 b$ depends upon the atmospheric pressure b.

Instead of integration we must here use approximately a summation for each day individually. It is, moreover, sufficient to operate with the hourly means for each month.

This calculation as effected for several stations, gives results that accord satisfactorily with the observations. If D designates the monthly mean of ηd, WD the monthly mean of ηwd, and z the number of days, then the total monthly evaporation is:

$$h=\mu[zD+\gamma z\,WD].\quad \text{[See footnote }^2\text{.]}$$

The constants in this equation have been determined for several stations as follows:

Vienna	$\mu=0.673$; $\gamma=0$
Pola	$\mu=0.726$; $\gamma=0$
St. Petersburg	$\mu=0.675$; $\gamma=0$
Paris (Piche evaporometer)	$\mu=0.769$; $\gamma=0.058$

In the proceedings of the Academy of Vienna, Stefan (3) gives a theory of evaporation in continuation of the experiments published by him in 1874. The experiments were made on fluids more volatile than water and which did not absorb water from the air; the fluids were placed in tubes of small diameter whose upper ends were freely exposed. The following laws were deduced (4):

1. The rate of evaporation is proportional to the logarithm of a fraction whose numerator is the atmospheric pressure and whose denominator is the difference between the atmospheric pressure and the saturation vapor pressure.

2. The rate of evaporation of a liquid in a tube is inversely proportional to the distance from the open end of the tube down to the level of the liquid.

3. The rate of evaporation, u, is independent of the diameter of the tube.

These three laws are expressed by the formula:

$$11)\quad u=\frac{k}{h}\log\frac{p}{p-p_1}$$

where k is the constant of diffusion; p, the atmospheric pressure; p_1, the saturation vapor pressure; h, the distance of the level of the liquid below the open end of the tube.

Stefan then shows that the equation for the rate of evaporation leads to a form of equation that shows the analogy with conduction of heat and electrostatics. At the surface of the liquid the air is saturated and the tension of the vapor diminishes with the distance from this surface. He also finds for the quantity of vapor, v, passing in a unit of time through any level surface in the tube above the liquid, at which the vapor pressure is p_0, the following expression:

$$12)\quad v=-k\frac{dU}{dn}$$

where

$$U=\log\frac{p-p_0}{p-p_1}$$

and where dn is an element of the normal to the level surface under consideration. For the steady condition, where the quantity which passes through any level sur-

[2] [NOTE.—In this equation the author has substituted $\mu=\theta$ and $\gamma=\frac{\theta_1}{\theta}$ as now representing approximate generalizing factors that must be determined from the observations and are not to be confused with the γ of equation (2).—C. A.]

face is just equal to the quantity evaporated, the condition to be fulfilled is

$$13)\quad \frac{d^2U}{dx^2}+\frac{d^2U}{dy^2}+\frac{d^2U}{dz^2}=0,$$

where x, y, z are the coordinates of the point in space at which the steady condition obtains.

Stefan subsequently undertook the solution of the following problem: In an infinite plane, which neither gives out nor absorbs vapor, nor allows it to pass through, there is a hole filled with liquid, so that its level surface coincides with that of the plane; the liquid evaporates into the infinite atmosphere over the plane; it is required to calculate the quantity of vapor, V, passing from the liquid into the air when the evaporation has reached the stationary condition.

For a circular surface, or tube, he finds the quantity of evaporation:

$$14)\quad V=4ak\log\frac{p-p_0}{p-p_1}$$

$$V=4ak \text{ etc.},$$

and for small values of p_1 and p_0 this becomes:

$$15)\quad V=4ak\frac{p_1-p_0}{p}$$

where a is the radius of the circle and the other quantities have significations as already defined.

The quantity of evaporation, therefore, is not proportional to the surface of the evaporating liquid but to the circumference of the basin.

This result is also applicable to an elliptical circumference if the eccentricity is not more than 0.96.

The quantity of evaporation from a surface whose radius r is less than a is:

$$16)\quad V_1=V\left(1-\sqrt{1-\frac{r^2}{a^2}}\right)$$

If the level of the evaporating surface is at a distance, h, below the edge of the vessel, then the quantity of evaporation diminishes in the ratio:

$$\frac{r-h}{r}.$$

This investigation is certainly very interesting. Formula (15) has the same form as the first term of equation (1) of Weilenmann, or of the Dalton formula, which represents the rate of evaporation without considering the influence of the motion of the air, or the wind. But if the quantity evaporated is proportional to the circumference of the vessel then the depth of evaporated liquid must be in inverse ratio to the radius, and we must reach the conclusion that in a very extended vessel, as, for instance, the ocean, the depth evaporated would be 0.

On December 22, 1861, E. Stelling (**5**) presented to the Academy of Sciences at St. Petersburg, a treatise "On the Evaporation at Pavlovsk." He uses the Dalton-Weilenmann equation in the form:

$$17)\quad v=A\Sigma(S_1-s)+B\Sigma(S_1-s)w,$$

which is obtained by assuming the barometric pressure as constant and substituting in equation (8) of Weilenmann, as above given, the value of $(t-t_1)$ from his equation (7). A and B are constants, v the quantity of water evaporated; S_1 the vapor pressure for saturation at the temperature of the surface of the water, and s the actual vapor pressure of the vapor present in the air. The observations at Pavlovsk were made with an evaporometer floating in a basin so that the two levels of the water, within and without, were at the same heights; he finds sufficient accordance between observation and calculation.

Prof. Cleveland Abbe (**6**) proposes to employ the evaporometer in a shelter, as an integrating hygrometer. He illustrates this by the observations of FitzGerald (**7**) made in 1876–1882 at the Chestnut Hill Reservoir near Boston, where the following formula is given:

$$18)\quad E=0.0166(V-v)(1+\tfrac{1}{2}w)$$

E is the depth of water evaporated hourly, expressed in inches; V the maximum vapor pressure for the temperature of the water, also expressed in inches; v the maximum vapor pressure for the dew-point of the free air before it has had access to the evaporating surface; w the velocity of the wind, expressed in miles per hour, at the evaporating surface itself. From this formula the average dew-point for an hour or any other interval results as follows:

$$19)\quad v=V-\frac{60E}{1+\frac{1}{2}w}$$

Already in 1862 Tate (**2**, v. 23, p. 130) had proposed a certain form of evaporometer answering the purpose of a hygrometer (**8**).

Prof. Thomas Russell (**9**) communicates the lines of equal evaporation for the United States of North America, as calculated from the psychrometric observations made at the stations of the Signal Service. Basing his studies on the above-mentioned treatise of Stelling (**5**) and on observations made in 1888 at 19 stations with the Piche apparatus, which he reduces to observations over an open water surface and for a mean velocity of the wind of 13 kilometers (8 miles) per hour by dividing by the factor 1.33. Russell finds that the quantity evaporated can be expressed in inches by the following:

$$20)\quad V=[1.96\,p'+43.9(p'-p'')]\frac{30}{b}$$

where p' is the vapor pressure for the temperature of the wet-bulb and p'' the vapor pressure for the dew-point, both being expressed in inches.

Dr. W. Ule (**10**) speaks of the evaporating power of a climate, meaning thereby the greater or less ability of the air to desiccate a body. This desiccating power must be proportional to the vapor tension of the air and we have a measure of this climatic element in the variation in weight of a body. The intensity of the desiccating power and the rate of desiccation are to be distinguished from each other. Ule thinks that the weighing apparatus of Wild is well adapted to determine the rate of desiccation. He endeavors to calculate the quantity of evaporation by the following new formula:

$$21)\quad u=A\Sigma(t-t')w$$

where A is a constant, Σ is the sign of summation, t and t' the two psychrometric temperatures, or dry-bulb and wet-bulb, w the velocity of the wind. This is identi-

cal with the second part of my formula (5) above given; but this single expression can not be correct since it indicates that there would be no evaporation when $w=0$.

De Heen (11) publishes the results of observations on the evaporation when a current of gas flows over a liquid and finds the following equation for the rate of evaporation:

$$22) \quad u=AF(100-0.88f)\sqrt{V}$$

where F is the vapor pressure for saturation at the temperature of the liquid, f is the percentage of the relative humidity of the air before evaporation, V the velocity of the current, A is a constant.

INSTRUMENTS AND OBSERVATIONS.

Instruments.

Several arrangements have been proposed for the purpose of obtaining precise results with the least possible labor. The first observations were made by simply weighing a vessel filled with water at stated times. The successive steps in the development of evaporometers were as follows:

1869. Lamont, at Munich in 1869, described his evaporometer which consisted of two communicating tubes, one of them surmounted by a broad open basin for evaporation, the other having a piston and micrometer for the measurement of the depth evaporated.

1872. Prettner (12) employed a vessel in the form of a rain gage; it has a stopcock near the bottom by which the water equivalent of any rain that has fallen into the gage may be drawn off; there is also a fine stream of water at command by which the level of water in the evaporometer may be carefully raised at stated times daily, to the needle point that indicates a constant level.

1873. Piche, in France in 1873, proposed a graduated tube closed at the upper end, filled with water, and having the lower end covered with a small circular piece of bibulous paper from which the moisture evaporates. By reason of the cheapness of this apparatus, it has found many applications, chiefly in France, although its indications are much in excess of the evaporation from an open water surface in a vessel.

1874. F. Osnaghi (13), of Vienna, proposed an evaporometer in the form of a balance, with an index which is brought back to the first or standard reading by the addition of water flowing from a graduated tube. This instrument can also be adapted for self-registration.

1875. John Greiner (14), of Munich, constructed an apparatus in which a definite quantity of water after evaporation, flows into a graduated vessel for measurement and is then thrown away.

1875. The only method practicable throughout both summer and winter is that of weighing, and, in 1875, Wild, of St. Petersburg, provided 20 stations in Russia with instruments of his own invention consisting of a balance whose lever carries on one side the evaporating vessel while the other side is provided with a weight to counterbalance the vessel, and ends in an index showing, on a graduated scale, the quantity of moisture evaporated.

Analogous methods of observation have been used in Austria for 20 years under the direction of Hann.

Observations.

As already mentioned, the observations by Dalton in England, and Schübler in Germany, are the oldest. Then come the publications of Maurice at Geneva, 1796–97, who measured the evaporation from water and earth. By the same method Gasparin observed at Orange, France, in 1821–22. The annual evaporation and rainfall as found by these observers were:

Station.	Annual evaporation.		Annual rainfall.
	From water.	From earth.	
	Mm.	*Mm.*	*Mm.*
Geneva, 1796.....	1,210	402	654
Orange, 1821–22..	2,281	579	722

Schübler, at Tubingen, obtained 647 mm. as the annual evaporation in the shade. Stark, at Augsburg, from a series of 14 years' duration obtained 1627 mm. as the annual evaporation in the full sunshine. Schübler also investigated the influence of the wind, and found on the average an evaporation in windy weather double that in calm weather. The maximum rate of evaporation occurred with northwest winds in summer and southwest in winter; the minimum rate, with southwest winds in summer and southeast in winter. In 1826 Schübler found that a thickly grown field of grass during July and August evaporated twice as much as a surface of open water, both grass and water being in the shade. Since 1840, observations on evaporation have been made at Madeira and in the Azores; the annual amounts are: At Delgada, 765 mm.; St. Miguel, 1,050 mm; Funchal, 2,027 mm.

In 1855 Prof. Chapman, of Toronto, Canada, compared the evaporation of salt sea water with that of fresh lake water and found that the former was 54 per cent of the latter. In July, 1867, Prof. Ragona, of Modena, Italy, obtained nearly the same results, but found the percentage to vary with the temperature and moisture of the air.

According to Hartig forest areas evaporate less than an equivalent surface of water or of naked earth. Schübler found during the season of vegetation that the daily evaporation from one square foot of water surface was about 1 cubic inch, corresponding to an average depth of about 1 line, or one-twelfth of an inch; for naked earth he found 0.60 line and for forest 0.25 line. Lawes states that a wheat plant evaporates in one day ten times its own weight of water; in dry weather the leaves are slack and the evaporation diminishes (15).

Dufour (16), of Lausanne, published the results obtained since 1865 with his apparatus, which he calls the *siccimeter* and which is exposed to full sunshine. He found the annual average evaporation for the interval 1865–1870 to be 756 mm. and the average rainfall 924 mm.

Pfaff (17) in 1870 published his investigations on the influence of trees on the moisture of the air and the ground. Observations were made four times a day from May 18 to October 24. The evaporation from the branches was two or three times greater by day than by night; from fresh branches three and one-third times greater in the sunshine than in the shade. Unger had found the same result. The comparison with evaporation from an open water surface showed the latter to be from 1 to 13 times greater than the evaporation from an equal surface of leaves. The loss of water from a tree by evaporation is eight and one-third times the amount of rainfall on an area equal to that covered by the crown of the tree.

1873. Ebermayer, of Munich, in 1873 published the results of observations made in Bavaria on the influence

of the forest on moisture and evaporation. The mean of the years 1868–1870 shows that the evaporation from the forest as compared with the evaporation in the open field is 35 per cent in summer, 40 in the autumn, 47 in the winter, and 45 per cent in the spring. In the forest the evaporation from the naked ground saturated to a depth of one-half a foot, is a little more than that from an equal surface of water. The minimum ratio of the evaporation in the forest to that in the open field is 26 per cent in October and the maximum is 56 per cent in April. A cover of litter lessens the evaporation by 40 or 50 per cent in the forest and by 22 per cent in the open field. The evaporation from overgrown ground covered with litter is 85 per cent of that from the same surface free from litter.

1874. Marié-Davy, of Paris (Annuaire de Montsouris, 1873), gives a review of the observations hitherto made relating to the evaporation from the ground and its relation to the rainfall. The first observations are those of Maurice and Gasparin already mentioned. Then came the results obtained by E. Risler (**18**) in 1867–1869, at Calèves, Vaud, Switzerland, who prepared a field of 12.3 hectares for measurements of the rainfall and of the water drained from the ground. He found that on the average the rainfall was 971 mm. and that 256 mm. of the water flowed off, leaving a difference of 715 mm. to represent the evaporation. But if the field was well cultivated, in the summer time nothing ran off for a rainfall of from 30 to 100 mm. a month. In 1869, Risler also measured the quantity of water at various depths in the soil; on August 24–26, during very dry weather, and on September 10 and 11, after a considerable rainfall. In the springtime on digging into the ground he found that the water penetrated to a depth of 0.31 m. in broken soil; but only 0.29 m. in meadows, 0.14 m. in turf, 0.04 m. in a forest of small oaks, and 0.03 m. in a forest of tall oaks.

1869. At Montsouris near Paris, in 1869, July 20–28, Marié-Davy observed the evaporation of plants with the following results: From a field of turf, 33.4 mm.; from a field of beans, 25.7 mm.; of juniper, 16.8 mm.; and of thuja 12.8 mm. He found the evaporation from branches of trees to be as follows: Red beech, 8.2 per cent of the evaporation from open water; poplar and linden, 5.1 per cent; oak, 4.5 per cent; elm, 3.4 per cent. Similar experiments were made by Risler in 1870–71. He calculated the evaporation from the leaves contained in a vertical cylinder extending from the top of the foliage down to a base of 1 square meter of the surface of the ground and found the following daily averages in millimeters: Lucerne (medicago), 3.4 to 7.0; meadows, 3.1 to 7.3; wheat, 2.7 to 2.8; corn (maize), 2.3; fir trees 0.5 to 1.1; oak trees, 0.45 to 0.8.

1871. H. C. Russell, Sydney, New South Wales, has made and regularly published observations since 1871.

1879. Von Höhnel (**19**), of Vienna, in the "Mittheilungen a. d. forstlichen Versuchswesen Oesterreichs," Bd. II, pp. 47–90 (Abstract in Wollny Forsch., 1881, IV, pp. 435–445), published an interesting treatise "On the Transpiration of Forest Trees compared with the Meteorological Relations of the Forest." He mentions the earlier researches, esteeming those by Wollny of Munich as the best. These were made on plants with roots growing in zinc pots. He himself operated on whole trees five or six years old and from 50 to 80 centimeters high, growing in pots, taking all the necessary precautions. Von Höhnel found greatly varying amounts of water lost through the leaves. His experiments made from June to November 30, 1878, on 20 different species gave as the minimum loss 3,207 grams of water per 100 grams weight of dry leaves of the black fir; the maximum was 67,987 grams of water lost by 100 grams weight of the dry leaves of the birch. The rainfall on the ground area covered by the trees was found to be more than sufficient for restoring the water lost by transpiration. Wollny has shown that in the summer time nearly all of the rain water can be used up by the plants. One hectare of land covered with beech trees, averaging 115 years old, evaporates during the growing period from 3.6 to 5.4 millions of kilograms; a single beech tree on an average for the whole season evaporates 50 kilograms per day; but in the summer time the daily average is 75 kilograms. For smaller trees from 50 to 60 years old the corresponding amounts are 2.33 million kilograms per hectare per season, and 10 and 15 kilograms per tree daily during the season and during the summer, respectively. For trees from 30 to 40 years old the amounts are 0.68 million kilograms per hectare during the season and 1.0 and 1.4 kilograms per tree daily during the season and during the summer, respectively. The amount of rainfall during the same season of vegetation, June to November, 1878, was at least 3,000,000 kilograms per hectare and for the whole year 7,000,000 kilograms. The water lost by transpiration in a summer's day from 1 hectare of beeches is 45,000 kilograms for the trees 115 years of age; 20,000 for trees 50 or 60 years of age; and 5,000 for trees 30 or 40 years of age.

1880. E. Stelling (**20**), of St. Petersburg, publishes the annual variation of evaporation at 20 Russian stations since 1875. The variations depending on geographical position are exceedingly large; the total annual evaporation varies from 251 mm. at Novo-Alexandria to 2,321 mm. at Petro-Alexandrovsk.

1882. Prof. Th. Langer (**21**) from observations with four Piche evaporometers at Mödling, near Vienna, finds the following relative results: Calling the amount evaporated in the sunshine and ordinary air 100; in the sunshine but near a great basin of water it was 98.3; in an instrument shelter (von Lorenz pattern), 98.3; in the ordinary wooden shelter of the meteorological station at Mödling, 62.

1884. Carl Eser (**22**) publishes the results of observations on the influence of the physical and chemical properties of the soil on its evaporating power. His work was done in the laboratory and experiment field at Munich, and he states several general connections between evaporation, the moisture of the ground, the depth from which evaporation comes, the nature of the surface, the organic and inorganic contents of the soil, the fineness and coarseness of the soil, its color, its covering of living plants or of dead and dry material, its inclination to the sun's rays, etc. The laws deduced by him are of great interest but are so numerous that I have not the space to communicate all of them. In the saturated state all kinds of soil evaporate nearly the same amount. The loss of water at the surface is restored from below by capillarity as long as the water stored up in the soil exceeds 50 per cent of its maximum capacity. After this superficial layer has been greatly dried the influence of insolation, wind, etc., in producing further evaporation is appreciably diminished. Garden mold evaporates the most water; sand evaporates least. A cover of living plants evaporates the greatest quantity of water; one of of dry materials the least. Adding salts to the soil in the usual quantities for fertilizing purposes has no appreciable effect on the evaporation.

1881. J. B. Lawes, J. H. Gilbert, and R. Warington (23) in their treatise on the amount and composition of the rain water and drainage water at Rothamsted communicate investigations made by means of the lysimeter, using vessels the surfaces of which were each 0.001 of an acre, and which were filled with soil in its natural state. For the period 1870–1880 they found the following average results:

Rothamsted evaporation results, 1870–1880.

Season.	Rainfall.	Drainage water.	Evaporation.
	Inches.	*Inches.*	*Inches.*
April-September.....	16.36	4.39	11.97
October-March.......	14.67	9.10	5.58
Total, year.....	31.03	13.49	17.55

1887. John Murray (24) gives the calculated total annual rainfall on the land surface of the globe, based on the rain maps of Loomis and a comparison of the "run-off" and the evaporation at different latitudes, from 60° N. to 40° S. For the total land surface of the globe the annual rainfall amounts to 111,800 cubic kilometers; the water running off is 24,600 and the water evaporated is 87,200 cubic kilometers.

1886. Dom. Ragona (25) gives the relative evaporation in sunshine and shade at two stations having different positions and altitudes. At both stations the maximum ratio follows the minimum of actual evaporation at an interval of 16 days, and the minimum ratio follows the maximum evaporation at the same interval of time.

1890. Ang. Batelli (26), of Riva, near Turin, has made comparative measurements of the evaporation from open water and saturated soil in sunshine and in shade. He finds that more water is evaporated during the period of rising temperature, from the moist soil than from the surface of water; but with falling temperature less is evaporated from the ground than from the water. During an increasing velocity of the wind the evaporation from open water increases more rapidly than from the moist ground. An increase in the humidity of the air favors evaporation from the ground more than evaporation from water.

1890. Prof. Alexander Woeikoff (27) replies to a criticism on his work on the evaporation from and the condensation on snow and ice surfaces, and states that the observations of Weyprecht show that in winter time the evaporation is greater than the condensation and that in general this is true whenever the dew point is lower than the melting point of ice. Dr. P. A. Müller (28) of St. Petersburg confirms Woeikoff's statement by means of observations, made at the request of Abels, at Catherinenburg from December 21, 1890, to February 28, 1891, which showed that evaporation took place during 73 per cent of the hours of observation, but condensation during only 23 per cent.

1889. Symons (29) enumerates several evaporometers and quotes the results obtained by their use. Among these Col. Rogers Field, observing at Strathfield Turgiss from 1870 to 1883, with a water basin of 689 square feet area and 2 feet deep, found the mean annual evaporation to be 448 mm.; the minimum was 347 mm. in 1879 and the maximum 599 mm. in 1870. The same vessel exposed in London by Symons gave 90 mm. less than at Strathfield.

1892. Prof. Franklin H. King (30) published his "Observations and Experiments on the Fluctuations in the Level and Rate of Movement of Ground Water on the Wisconsin Agricultural Experiment Farm and at Whitewater, Wis." The observations were begun in 1888 with the design of investigating how far the daily periodic evaporation from naked ground or soil covered with vegetation could influence the quantity of water stored up in the soil beneath. A field of 11 hectares was at his disposition, which was at first provided with 24 wells connected with a system of drainage pipes; then 21 more were added, in digging which due regard was had to the variations in the topography of the land, distance to standing water, character of the soil, and the kinds of vegetation. After 1891 self-registering instruments of his own invention were employed. There was found to be a variation in the height of the level of the ground water in inverse ratio to the changes of atmospheric pressure, but in the same direction as the changes in temperature; in the neighborhood of cultivated ground the level of the ground water was depressed more than near naked ground.

In these few lines I have attemped to mention the most important researches on evaporation, both theoretical and practical. For want of space it was impossible to enumerate the results of the regular observations now being made in Russia, Austria-Hungary, Germany, France, Italy, England, and the United States, which are regularly published, as well as those at Manila and the Azores. I hope that nothing important has been omitted.

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REPORT OF THE METEOROLOGICAL STATION AT BERKELEY, CAL., FOR THE YEAR ENDING JUNE 30, 1913.[1]

By WILLIAM GARDNER REED, Ph. D.

[Dated University of California, Berkeley, Cal., Apr. 7, 1914.]

The University of California has carried on meteorological work at Berkeley (lat. 37° 52′ N., long. 122° 16′ W. Gr.; H, 98 meters; h_t, 1.5 meters; h_r, 4.6 meters) since October 16, 1886, in cooperation with the United States Signal Service and its successor, the Weather Bureau. This work was a part of the activities of the Students' Observatory until July 1, 1912, when it passed to the Department of Geography. This report is the first of a series of annual reports to be issued by the university.

During the fiscal year ending June 30, 1913, the following observations were made at 8 a. m. and 8 p. m. Pacific time:

1. Temperature of the air (dry-bulb thermometer).
2. Temperature of evaporation (wet-bulb thermometer).
3. Maximum temperature in the preceding 12 hours.
4. Minimum temperature in the preceding 12 hours.
5. Pressure of the air.
6. Amount of cloud, and weather.
7. Wind direction and estimated velocity.
8. Precipitation in the preceding 12 hours.

In addition to the observations at the regular hours, a record has been kept of the general character and prevailing wind direction of each day, the times of beginning and ending of precipitation, of the occurrence and character of fog, and of the occurrence of frost; an attempt has been made to record occasional meteorological phenomena of interest. The recording instruments have furnished continuous records of air temperature, air pressure, and relative humidity; these automatic records are complete from the times of the installation of the instruments and are correct except for such errors as are inherent in the instruments and which are not large.

The results of the observations have been recorded as made upon blank forms of the United States Weather Bureau. In addition to the figures obtained by observation, the following have been computed for each observation: Air pressure, corrected for temperature and local gravity; air pressure at sea level; dew point; relative humidity; and pressure of aqueous vapor. The range of temperature and the mean temperature for each day, the change from the mean of the preceding day, and the total precipitation for each day have been computed.

The instruments were exposed on the campus of the University at Berkeley, 19 kilometers (12 miles) east-northeast from the Golden Gate and the Pacific Ocean. The slope from the campus to San Francisco Bay is gentle, about 90 meters, 300 feet, in 3 kilometers, 2 miles. To the east the Berkeley Hills rise abruptly to elevations of over 300 meters, 1,000 feet, above sea level. The thermometer shelter and the rain gage are located at the Students' Observatory, on the west side of a small hill. This location probably provides good air drainage, with the result that temperatures at the location of the thermometers are probably higher than those at the bottom of the valley a few hundred meters away.

A summary of the meteorological conditions at Berkeley for the year will be found in Table 1 [omitted].

It was deemed advisable to use the C. G. S. system of absolute units as this report begins a new series and no previous reports have determined the style so that rational units may be used without complication. For this reason the question was decided wholly on the basis of the proper units.

Owing to a change in the thermometer exposure the temperatures for the year are not strictly comparable with those of preceding years. In general the temperatures under the freer new exposure show higher maxima and lower minima than under the former conditions.

Table 1 [omitted] shows the weather conditions for each month of the year. Days with less than three-tenths of the sky was cloud covered through the day, or on which the sky cloud covered for less than three-tenths of the time, were recorded as clear. Days with more than seven-tenths of the sky covered through the day, or cloudy more than seven-tenths of the time, were recorded as cloudy. All other days were recorded as partly cloudy. The partly cloudy days fall into two classes, those on which the sky was more than three but less than seven-tenths cloudy throughout the day, and those on which the sky was overcast or nearly so for a part of the day and clear for a part of the day; in either case the average amount of cloud for the day was between three-tenths and seven-tenths. The type of day on which the sky was partly cloudy throughout the day is more usual in the winter than in the summer months; it is generally associated with the margin of a cyclone, and may occur at the beginning or toward the end of a passage with the center near the station, or during the passage of a cyclone with the center at some distance from the station. The other type of partly cloudy day is probably the more common at Berkeley. In summer this type occurs with fog or "high fog" in the morning or evening hours, or both, while the greater part of the daytime hours are clear. In winter there is a similar condition when "tule fogs" have drifted southward from the marshes of Suisun Bay and the Sacramento River. The two types of partly cloudy day are the cyclonic, which is the first-mentioned, and the noncyclonic of the summer and the anticyclonic of the winter, which together constitute the second type mentioned.

The monthly extreme temperatures since the opening of the station are given in Table 2.

[1] *Abstract of* University of California Publications in Geography, v. 1 (No. 6), pp. 247-306, issued Apr. 7, 1914.

TABLE 2.—*Extreme temperatures at University of California, July 1, 1887, to June 30, 1913.*

Month.	Maximum.			Minimum.		
	° *A.*	° *F.*	*Date.*	° *A.*	° *F.*	*Date.*
July	309.3	97.3	7,1905	278.7	42.3	29,1899
August	307.1	93.4	22,1891	281.0	46.4	31,1905
September	311.2	100.8	18,1912	280.7	45.9	28,1905
October	307.4	94.0	8,1899	277.1	39.3	18,1905
November	300.8	82.0	16,1895	273.6	33.0	28,1905
December	293.9	69.6	24,1901	272.4	31.0	24,1905
January	298.0	77.0	26,1899	269.1	24.9	14,1888
February	299.4	79.5	18,1899	271.4	29.2	12,1905
March	298.8	78.5	29,1911	274.1	33.9	30,1905
April	303.3	86.6	24,1913	275.2	36.0	19,1896
May	306.6	92.5	26,1896	277.4	39.9	1,1899
June	311.4	101.1	6,1903	278.8	42.4	2,1903
Year	311.4	101.1	Je.6,1903	269.1	24.9	Jn.14,1888

NOTE.—Minimum temperatures for January and February, 1908, are not available.

PRECIPITATION.

The total precipitation of all kinds for the year 1912–13 was 397.2 millimeters, 15.63 inches. The monthly and seasonal rainfall of Berkeley from 1887 to 1912 has been compiled and was published in the Monthly Weather Review for April, 1913.[2] In addition to these two, the monthly rainfall and the total from July 1 to the end of each month, with the departures from the average for the same period, have been compiled for Table 3.

TABLE 3.—*Monthly and accumulated precipitation at University of California for 1912–13 with averages for 26 years and departures from the averages.*

Month.	Monthly.		Accumulated to end of month.		Average accumulated.		Departure 1912-13.	
1912.	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*
July	0.0	0.0	0.0	0.0	0.5	0.02	− 0.5	− 0.02
August	0.0	0.0	0.0	0.0	1.5	0.06	− 1.5	− 0.06
September	37.1	1.46	37.1	1.46	16.8	0.66	+ 20.3	+ 0.80
October	17.8	0.70	54.9	2.16	53.6	2.11	+ 1.3	+ 0.05
November	98.8	3.89	153.7	6.05	119.3	4.70	+ 34.4	+ 1.35
December	41.2	1.62	194.9	7.67	223.4	8.80	− 28.5	− 1.13
1913.								
January	96.0	3.78	290.9	11.45	368.9	14.35	− 78.0	− 3.08
February	16.3	0.64	307.2	12.09	470.8	18.54	−163.6	− 6.45
March	50.3	1.98	357.5	14.07	593.6	23.37	−236.1	− 9.30
April	14.5	0.57	372.0	14.64	630.5	24.82	−258.5	−10.18
May	25.2	0.99	397.2	15.63	659.5	25.96	−262.3	−10.33
June	T.	T.	397.2	15.63	664.9	26.17	−267.7	−10.54
1912–13.								
Season	397.2	15.63	397.2	15.63	664.9	26.17	−267.7	−10.54

The rainfall year was one of marked shortage in precipitation, as may be seen from an examination of Table 3. By itself the past year will stand out as one of the very dryest years of the record, but the condition of drought is especially noteworthy because the preceding season, that of 1911–12, was one of very little rainfall. Never since the establishment of the station have two such dry seasons occurred in succession, and consequently there is a marked shortage at the end of the season of 1912–13.

The number of days with precipitation amounting to 0.25 millimeter, 0.01 inch, or more, were 58 during the year, and the number of days with 1.0 millimeter, 0.04 inch, or more, were 46. The average for the 26 years is 65 days, with 0.25 millimeter, 0.01 inch, and 53 days with 1.0 millimeter, 0.04 inch. These days are those on which the amounts were collected by the rain gage; there may have been a few other days on which the amounts fell, but the catch of the gage is probably not far from the true amount of rainfall. On certain days, which number about five for the year, the precipitation was collected from fog, but the total amount from this source is small, probably not over 1.25 millimeters, 0.05 inch, for the whole year. All the other days on which 0.25 millimeter, 0.01 inch, was collected are to be regarded as true rainy days, especially those on which more than 1.0 millimeter, 0.04 inch, was recorded, as in no case did the precipitation from fog much exceed the minimum measurable amount.

Cyclonic rainfalls.

Although practically all the rain at Berkeley is the result of cyclonic activity, it has not been easy in all cases to assign the precipitation of a given day to a particular cyclone. In fact, the cyclonic relations in the Pacific coast region are somewhat complicated, rather important pressure fluctuations taking place while a single cyclone seems to be the dominant control of the weather, instead of the simpler fall in pressure as the cyclone approaches and the rise in pressure after the center has passed. In view of the importance of the cyclone as the control of precipitation at Berkeley, Table 4 has been constructed. This table includes all the precipitation for times at which depressions or unsettled conditions of pressure could be determined from the barograph trace. By a somewhat liberal interpretation it has been possible to include under the 18 cyclones given in Table 4 precipitation amounting to 394.4 millimeters, 15.52 inches, or all but 2.8 millimeters, 0.11 inches, of the total for the year. Of this amount 1.0 millimeter, 0.04 inch, was from fog, which leaves only 1.8 millimeters, 0.07 inch, of the rain not accounted for by cyclones. This amount was all recorded on April 12, and is shown by the weather maps to be almost surely of cyclonic origin; it has been omitted from Table 4 because the barograph trace does not show clear cyclonic characteristics.

TABLE 4.—*Cyclonic rainfall at Berkeley, Cal., 1912–13.*

No.	Date.	Precipitation.		Barograph trace.	Weather map notes.
		Mm.	*In.*		
1	Sept. 2	2.3	0.09	Faint depression	Low over Vancouver 2d; breaking up 3d.
2	Sept. 5-6	34.8	1.37	....do	Low off Washington coast, moving east.
3	Oct. 22-29	17.8	0.70	Unsettled	Strong low off Washington 21st-23d, moving east; low crossing Washington 24th-26th; lows in southern plateau States and Washington 26th-29th.
4	Nov. 3-10	90.1	3.55	Unsettled with two moderate depressions.	Lows crossing Washington and Oregon; subordinate lows in Nevada.
5	Nov. 12-15	1.3	0.05	Moderate depression	
6	Nov. 18-20	7.4	0.29	....do	Low crossing southern British Columbia.
7	Dec. 13-17	38.4	1.51	Marked depression 14th and 15th.	Large low crossing southern British Columbia.
8	Dec. 30-31	2.8	0.11	Weak depression	Large low off coast of northwestern United States.
9	Jan. 7-11	20.1	0.79	Marked depression	Low in Northwestern States, later in the plateau States.
10	Jan. 11-19	74.7	2.94	Marked depression 11th-17th, unsettled 17th-19th.	Large low central in Northwestern States, moving east.
11	Jan. 20-23	1.0	0.04	Marked depression	Follower of the preceding, moving east.
12	Feb. 5-10	2.8	0.11	....do	Marked low crossing southern California.
13	Feb. 20-28	12.7	0.50	Moderate depression 20th-22d, marked depression 23d-28th.	Large low area central in British Columbia and Arizona, later in California, Northwest and plateau States, Oregon, California, and moving east.
14	Mar. 15-25	50.3	1.98	Depressions: Marked 15th-18th, unsettled 18th-21st, weak 21st-26th.	Low in British Columbia and Washington with trough to Arizona; moving east.
15	Apr. 2-8	12.7	0.50	Weak depression	Low in British Columbia.
16	May 8-9	5.6	0.22	Very faint depression	Weak low in Northwestern States.
17	May 15-19	8.9	0.35	Faint depression	Low over Nevada, moving east.
18	May 27-29	10.7	0.42	Very weak depression.	Low over Nevada.

[2] W. G. Reed, The rainfall of Berkeley, Cal. Mo. Weath. Rev., Washington, 1913, 41, p. 625-627. Published in more extended form in Univ. Calif. Publ. Geog., 1, p. 63-79 (No. 2, 1913).

WIND.

Observations of wind direction have been made at the morning and evening hours; the results are tabulated under the heading "Winds at 8 h. and 20 h. (number of observations)" in Table 1 [omitted.] This part of the table shows the winds actually observed on the campus in the morning and evening as far as they can be determined. All wind directions at Berkeley must be estimated, as the equipment of the station does not include a vane and no accurate compass directions have been laid down on the campus. In general the observations have been made from the drift of smoke and from the flag on the campus, so that the directions must be regarded as approximations and not the actual conditions of air movement. These give fairly accurate directions for the morning hour, but the directions are more uncertain at night.

The topography of Berkeley and its vicinity probably has a strong local influence on the wind direction, which may amount to actual control in some cases. The canyon of Strawberry Creek through the western line of hills bordering the campus must have some effect on the wind direction. Although no detailed study has been made of the local air drainage, it is certain from casual observations that there is frequently in the evening a draft down from Strawberry Canyon across the campus. There are, however, no observations which show whether there is an up-canyon draft in the daytime. It would not be surprising to find that the trend of the faces of the hills and the existence of Strawberry Canyon exert a marked influence on the direction of the wind at the university campus.

CONCLUSION.

The mean annual temperature at Berkeley during the year 1912–13 was about 287°A., 57°F., with a mean annual range of 10°A., 19°F., and an extreme range of over 40°A., 70°F. The mean maximum temperature was 292°A., 66°F., and the mean minimum 281°A., 47°F. The mean monthly range was 21°A., 38°F., the mean daily range 10°A., 19°F., and the mean change from day to day 1.4°A., 2.6°F. September was the warmest month of the year and January was the coldest; January was probably abnormally cold, but no other month had a very unusual temperature. Frost was probably more frequent in December and January than the average for the whole period of the record for these months.

The pressure of the water vapor of the atmosphere was in general less than 13 millibars (10.0 millimeters or 0.4 inch of mercury), the relative humidity averaged slightly more than 80 per cent morning and night, and the mean dew point was about 275° A., 36° F., in the winter and about 286° A., 56° F., in summer. The vapor pressure and the dew point showed a strong tendency to vary with the air temperature. Not quite half the days of the year were generally clear, but only a quarter of the days were generally cloudy and many of the partly cloudy days had several hours of bright sunshine. Fog was observed on 40 days and "high fog" on about as many more, which is probably about the average for Berkeley.

The total precipitation for the year was 397.2 millimeters, 15.63 inches, which is 267.7 millimeters, 10.54 inches, less than the average. September and November had more than the average rainfall, but all the other months had less than the average. Snow fell on one day in January. There were 58 rainy days during the year, which is slightly less than the average; in five months of the year there were more than the average number of rainy days, and in five there were less than the average number, July and August being omitted from consideration, as they are generally dry. The heaviest fall of rain in any one day of the year was 60.7 millimeters, 2.39 inches, on November 6; this was the only day on which as much as 25 millimeters, 1 inch, fell. The precipitation of the year was mainly the result of 18 cyclones, the centers of most of which passed far north of Berkeley, but the cyclones were near enough to control the weather at the station.

The wind was largely from southerly and westerly directions in the average for the year, both in the prevailing directions by days and at the observation hours. The westerly element was more marked in the summer months. Calm days were rare, although no wind movement was observed at about one-fifth of the observation hours.

ELECTRIC PARAGRÊLES.[1]

By A. ANGOT, Director, Bureau Central Météorologique de France.

[Translated by R. E. Edwards from Annuaire, Soc. météorol. de France, Mars, 1914.]

It is unnecessary to review the objections that I have heretofore given against the use of cannons or rockets for protection from hail. These processes have always seemed to me to be of doubtful efficiency; but they have their origin at least in a legitimate idea, they seek to attack a thunderstorm cloud directly and to destroy it.

The electric "niagara" apparently has not even this advantage. It is founded on the erroneous idea that hail is an electrical phenomenon.

Without wishing to enter into the details of the matter, it is sufficient to point out the fact that the electrical manifestations, lightning and thunder, are not the cause of storms, but a result of much more extensive meteorological phenomena which are connected with the general circulation of the atmosphere.

The primary phenomenon is an ascending current (generally accompanied by a barometric depression) which causes the formation of a special cloud, designated cumulo-nimbus by meteorologists. In certain cases it has been possible to follow the process of the ascending air current and of the corresponding cumulo-nimbus over very large areas, such as the whole of Europe, Great Britain, and Russia.

The ascending current and the cumulo-nimbus which it produces, undergo in their progress constant modifications; the local manifestations depend on the violence of the phenomena.

Everywhere we may observe the passage of the cumulo-nimbus; over certain regions this passage will be accompanied by more or less heavy showers, phenomena less general than the cloud; in more limited regions, more serious indications will be manifested; lightning and thunder; that is, a thunderstorm and hail. But these last two indications are not necessarily associated. Thunderstorms may occur without hail or hail without thunderstorms. Admitting that a "niagara"—that is, a lightning rod—can act on electrical manifestations, we do not see what influence it could exert on a phenomenon such as hail, in whose production electricity plays no part.

Moreover, hail forms at altitudes such as seem to be not easily accessible with our means of action. In order that a hailstone may form, it is necessary that the surrounding temperature be less than 0° C. Supposing that the temperature at the ground be only 25° C., which is

[1] Extrait de la communication faite à la Société nationale d'agriculture de France, séance du 4 février, 1914.

not excessive for a summer thunderstorm, the temperature of 0° C. will be encountered at an altitude of not less than 3,000 meters and often more.

To return to the action of "niagaras" on hail; I will cite only three cases, taken from localities where the observations are unquestioned.

Since a "niagara" was installed on the Eiffel Tower, the falls of hail have not been less frequent than formerly in the quarter of the Champ-de-Mars and especially at the Bureau Central Météorologique [near the base of the Tower], where they have been observed and recorded with the greatest of care. The complete list of hail falls can be published, if necessary.

The lower station of the Observatoire de Puy-de-Dôme is situated in a freely exposed location on a plateau, in the suburbs of Clermont-Ferrand. A steel skeleton tower (pylône en fer) 31 meters high, has been constructed to carry the anemometers and is equipped with a "niagara." In the annual report of the director we read that hail fell twice on the "niagara" in 1912 and four times in 1913. Particularly on August 29, 1913, the hailstones averaged the size of a pigeon's egg and were sometimes the size of a hen's egg. Mr. Mathias concludes from his observations that "the hail-dispelling ability of the 'niagara,' theoretically improbable, has not been experimentally demonstrated."

Still more instructive observations are those of the Observatoire de Bordeaux, situated at Floirac, which was provided with a "niagara" September 22, 1912. The commune of Floirac was devastated by hail on August 15, 1887; but for the succeeding 25 years it had been immune. Again in 1912, two disastrous falls of hail occurred at Floirac, one on July 5, before the installation of the "niagara," the second on October 20, when a heavy shower of very large, hard hailstones fell upon the "niagara" itself during a period of two and a half minutes. Stones picked up 35 minutes after the fall were found to be spherical in form and opaque and on an average the size of a small pea. One of the observatory officials collected and sketched a number of very remarkable forms of hailstones that had fallen at the foot of or within less than 40 meters of the steel tower of the "niagara."

These observations show how necessary it is to be conservative in expressing appreciation of the efficiency of hail-fighting apparatus. Because there has been no hail in a place, one has no right to conclude that the processes employed, cannons, rockets, or "niagaras," have prevented the hail. A region devastated by hail may be spared for 25 years, although not supplied with any form of protection, and hail may visit it again twice in the same year a paragrêle is installed at that place.

Under these conditions, I should not recommend the extension of the system of electric "niagaras;" in my opinion there are already more than enough to continue observations which, it seems to me, must inevitably lead to negative conclusions.

On the contrary, it will be very important to have numerous exact observations on the falls of hail in France. At the present time the available stations do not enable us to draw charts showing the distribution of hail, that are sufficiently detailed to be valuable. I pointed out this insufficiency more than 10 years ago in studying the storms of 1903, and I have shown that in order to make a complete study of the distribution of hail over a small Department like the Rhône, it would be necessary to have from 280 to 300 stations uniformly distributed. A large Department like the Gironde or the Dordogne would need about 1,000 stations. These numbers suffice to show the difficulties of the problem.

A NEW TURBIDIMETER.

By P. V. WELLS.

[Dated U. S. Bureau of Standards, Apr. 29, 1914.]

[Author's abstract.]

A systematic study of turbidity for the purpose of defining a proper standard is much needed. The paper describes an instrument in which the turbidity is measured by the light diffracted from the particles. A collimated beam from an intense source such as a Nernst or tungsten filament passes through a variable thickness of the turbid medium, and is totally reflected by a prism, thence forming a uniform beam in one field of a photometer. The diffracted light is not totally reflected, but is refracted by the prism into the other aperture of the photometer. Thus the reading is a function of the ratio of the intensities of the light scattered and transmitted, which, in turn, varies with the turbidity.

The instrument is adapted to liquids, gases, and solid plates. Minute traces are measurable with photometric precision, while the range is widened by varying the thickness of the medium. The characteristics of a preliminary instrument constructed at the Bureau of Standards are discussed.

In connection with the above, Dr. S. W. Stratton, Director, United States Bureau of Standards, writes: "It may be of interest to know that the bureau is planning to use a form of the instrument in the study of fogs as a part of the work of the [International] Ice Patrol."

THE LOWEST TEMPERATURE OBTAINABLE WITH SALT AND ICE.[1]

By ROSS AIKEN GORTNER, Physiological Chemist.

[Dated, Carnegie Instit. of Washington, Dept. Exper. Evolution.]

* * * While discussing freezing mixtures with a friend recently I stated that a temperature of −19° C. could be easily obtained and maintained for some hours with an ice and salt mixture. My friend questioned the accuracy of the thermometer, inasmuch as − 19° C. is below 0° F. (− 17.78° C.). I have, therefore, made a careful test to ascertain whether an ice and salt mixture may not show a lower temperature than 0° F.

About a gallon of finely chopped, hard ice was mixed with a quart or more of coarse salt in a water-tight wooden box, the wooden box being used because of the insulation which it afforded. The temperature was then observed with five thermometers. * * *

Thermometers 1, 2, and 3 ["Anchutz normal"] gave the same temperature for the ice and salt mixture, i. e., −21° C., which is the equivalent of 5.8° below zero Fahrenheit. Thermometer 4 was graduated only to −19° C., and the mercury was some distance below the bottom of the scale. A reading of −20° to −21° C. was made [by extrapolation]. Thermometer 5 gave a minimum of −4° F., while the Weather Bureau [minimum] thermometer (No. 6) gave a reading of −5° F. [−20.56° C.].

Previous to this experiment I had filled a wooden box holding perhaps 30 pounds of ice with a freezing mixture in the evening and placed it in an empty ice box to

[1] Extract from an article in Science, New York, Apr. 17, 1914, (N. S.), 39, p. 584-585.

conserve ice. In the morning I noted a temperature of $-19°$ C. [$-2.2°$ F.].

From these experiments I am convinced that 0° F. is not "the lowest temperature obtainable with ice and salt." Just what the "lowest temperature" is I am unable to state, having failed to secure a greater lowering than $-21°$ C. Theoretically the lowest temperature should be the cryohydric point ($-22°$ to $-23°$ C.), where the cryohydrate, ice and salt, containing 23.6 per cent of NaCl, separates.

THE MOTION OF THE SOLAR ATMOSPHERE.

Meteorologists have long been interested in the studies of the solar atmosphere by astronomers; hoping therefrom to derive some suggestions that may contribute to our knowledge of the earth's atmosphere. One of the most interesting points of resemblance between the atmospheres of the sun and the earth has recently been published by the Observatory of Zurich.[1] It is an elaborate study by Wilhelm Brenner on the proper motions of groups of sun spots, which perhaps is the same thing as the motion of the sun's atmosphere within a region of sun spots. He first determines the accuracy of the heliographic positions of the spots within that region. Of course, the general movement of the region has long been understood as corresponding to that of our hurricanes in our Northern and Southern Hemispheres. But within each group of spots there is a divergence of motion among the individual spots corresponding very closely to the outflow of atmosphere from our own regions of high pressure. In other words, the fragments diverge from each other, separating as they are removed from the center of the region, and also rotating anticlockwise in the Northern Hemisphere. Every new increase in the activity of any given group is accompanied by an increase in the divergence of the spots, but this increase is rather feebler than it was when the group of spots first began to develop. This was true in 90 per cent of the groups investigated.

It seems probable that the strength of the divergence depends upon and may be proportional to the energy of the development of the group. In fact Brenner has every reason to believe that there is no connection between the magnitude of the divergence within any spot and the activity of the so-called 11-year period, or with the heliographic latitude.

The possible connection between Brenner's results and certain analogous phenomena consists in the interesting fact that his results agree with the hypothesis that each spot, large or small, and each group of spots, is an eruption or boiling up from within the solar atmosphere. This causes a heaping up over the boiling region, above which the solar gases with their dark and bright spots, flow slowly outward and downward with the anticyclonic whirl without seriously affecting the general motion of the group across the solar surface.—[C. A.]

LIGHTNING AT MOUNT WILSON OBSERVATORY.

By WENDELL P. HOGE, Night Assistant.

[Dated Mount Wilson, Cal., Mar. 30, 1914.]

Yesterday, Sunday, March 29, at 3:30 p. m., the mountain top [elevation, 5,886 feet] was in the midst of a severe snowstorm following a light rain during the forenoon. Fog covered the mountain. Temperature about 31° F.; wind 12 to 15 miles from the southeast. The wind had risen from very light to brisk about 1 p. m. I was sitting near a window in a one-story concrete metal-roofed building known as the observatory laboratory and study. While the snow was falling quite rapidly in moderate-sized flakes, a rather bright flash of lightning came, followed after an interval of between one-fourth to one-half of a second by a single, short, sharp report quite similar to that of a .22 rifle shot. Then absolute silence. In about five minutes a second flash came, much brighter than the first. This was accompanied instantly by a rather faint very sharp crack, very similar in sound to the spark frequently produced in the laboratory. Then silence again. No more flashes were noticed. Such bright flashes of lightning with such exceedingly wild reports following, I have not before experienced.

POPULAR MISCONCEPTIONS.

Nearly every day brings to the attention of the Editor renewed evidence of the need of education; the abundance of ideas, the rashness of hasty statements, in conversation, in the daily press, and in letters from fellow citizens who wish their ideas to be tested by some expert. In general, these crude notions have occurred to active minds who wish to inquire into the ways of Nature and yet are not willing to accept the principles of research—principles and axioms that have been long since well established. It would seem that a large fraction of mankind is still in the condition of mind that characterized the world before the days of Copernicus, Galileo, and Isaac Newton. It was Columbus who first practically endeavored to verify his theory that the world was not flat but a sphere, and Magellan completed the demonstration. It was Copernicus who maintained that the earth revolved daily on its axis and annually around the sun, and gave a satisfactory demonstration of the truth of his theory. It was Galileo who maintained that bodies fall toward the earth by gravitation and demonstrated the accuracy of his idea. It was Sir Isaac Newton who maintained that this gravitation was universal and that the sun held the earth in its annual orbit, and that the earth held her moon in its monthly orbit, and gave a satisfactory demonstration of the correctness of this idea. And so we might trace the progress of knowledge from those early days down to the present time. Step by step those who have climbed the hill of science have perceived the possibility of some deeper insight into Nature and have been able to demonstrate some new principle. In every case, however, it has been necessary for the respective discoverer to appreciate whatever had already been discovered bearing on the points that he was especially interested in, before he could feel prepared to make additional progress in our knowledge of Nature. The consciousness that we are but beginners in the study of an almost infinite series of problems should make one very modest in his assertions as to how Nature must operate, or how the world was made, or what the possibilities of Nature ought to be. The pathway of science within the past 300 years is strewn with tens of thousands of suggestions that have fallen by the wayside and are long since forgotten; they have helped to show us what does not take place and what is not true and have thus paved the way, and eased the path, of those who have discovered what is true.

Our numerous correspondents must not be surprised or chagrined if in reply to the theories that seem to them

[1] Publikationen der Sternwarte des eidg. Polytechnikums zu Zurich. Bd. 5.

very plausible, they learn that we can not accept them, or that they are contrary to experience, or inconsistent with well established principles, or can only be of local and temporary importance. For example, if one man addresses the President of the United States claiming that the evaporation from plowed land in Kansas and Nebraska produced evaporation and haze until eventually rain fell and that nothing will produce rain except evaporation, he must not be surprised to have his communication referred to the Weather Bureau and to learn that the evaporation from Nebraska could only have produced a very small part of the rain, if indeed it had anything at all to do with the rain that fell over Kansas and Nebraska. If the same correspondent enthusiastically addresses the Secretary of the Interior as to the need of conserving the waters of the Platte River and increasing the reservoirs of water so as to stimulate evaporation, he must be told by the Director of the Geological Survey that rains which are to produce any appreciable good effect generally result from conditions of such great extent that the water contributed by evaporation in Kansas and Nebraska would not be appreciable. Evidently such a persistent advocate of his own ideas is scarcely willing to accept as a finality the opinions of recognized experts. Why then should he not reason out the matter to suit himself; why ask a specialist to investigate the value of a crude idea whose value he could easily have settled to his own satisfaction by his own personal study? It would take him but a few minutes to figure out the quantity of rain that fell and the preceding quantity of moisture evaporated from the soil and, according to his theory, necessary to furnish that rain, e. g., if 8 inches of rain fell on a soil that had received no rain for three months and from which scarcely an inch in depth of water could have evaporated, then this 1 inch could not have produced those 8 inches.

Almost the same course of reasoning applies to a correspondent from Alabama, who maintains that carbonic-acid gas is increasing in the atmosphere and causing the climate to change toward the tropical conditions of earlier ages. Of course he has no observations to show that there was an extra amount of carbonic-acid gas in the atmosphere in past geological ages, and certainly there is nothing to show an appreciable increase in carbonic-acid gas in the free atmosphere during the past century. The so-called theory on which he bases his "Warning Number 2" is based upon his own idea as to the use of coal, petroleum, etc. He entirely ignores what we already know about counteracting influences that counterbalance the increasing danger that he anticipates, and that require the officials in Washington to dismiss his "theory" of the weather as wholly illusory.

The term *theory* is employed quite improperly in such cases. These correspondents are offering suggestions, well meant indeed, but not of sufficient importance to be called well considered theories. A *theory* with regard to any natural phenomenon is a plan or scheme based on principles that are verifiable by experiment, observation, and analysis; a rational explanation that agrees with all the facts and disagrees with none. It is only a very loose and popular error to speak of a *theory* when we mean merely a *hypothesis* or *speculation*. A proposed explanation, or a working hypothesis, is framed in order to account for any fact that is not well understood, and it is only after this hypothesis has been well established or, if necessary, replaced by successive approximations, that one is eventually justified in building up a rational theory. Speculations, hypotheses, and suggestions should not be called theories until one or more of them have been successfully demonstrated by experiment and by observation.

Another class of correspondents and newspaper writers are as apt to ignore the history of the progress of science as the above-mentioned writers ignore the philosophy of science. Thus, from one author we understand that the idea of the general adoption of rational meteorological units in this country is the result of the initiative taken by Prof. McAdie in 1908, whereas, his proposition of that year was but one of many that had been under discussion in all the weather bureaus of the world for many years previous, and, in fact, ever since the conception of the metric system of units. We are very glad that at Blue Hill Observatory Prof. McAdie will introduce the system advocated by Bjerknes and his followers.—[C. A.]

CONTINUOUS PICTURES OF THE WEATHER.

Among the many suggestions received by the Weather Bureau from well-meaning correspondents interested in the progress of the study of the atmosphere considered as a branch of physics and dynamics rather than as a branch of climatology, one correspondent desires a picture of weather changes and their relations to each other to be presented as a series of small daily maps, nine to a page, and continuous for a month and showing isobars, isotherms, rise or fall of temperature, the direction and force of the wind, cloudiness, rainfall, thunderstorms and tornadoes, and perhaps some other items, especially the absolute moisture, which latter can perhaps be given approximately for the total column of atmosphere over any station. Of course such a series of maps would have some value, but something similar has been published for many years by various European weather services, and now in place of this series of small maps the U. S. Weather Bureau has taken a far more important step by publishing that daily map of atmospheric temperature and pressure over the whole Northern Hemisphere that has for some years past proved so very useful in its long-range weather forecasts.

We are convinced that it is only by the study of atmospheric conditions over the whole Northern Hemisphere, as if photographed daily, that we shall ever be able to appreciate the preponderating influence of the diurnal rotation of the earth and the general circulation of the atmosphere as compared with the minor influence of sunshine, radiation, and moisture. That is to say, these last three influences that start the atmosphere in motion are completely overshadowed by the effect of that motion combined with the swift rotation of the earth. The relative importance of these influences on the atmosphere as a whole is quite analogous to their relative importance in the case of a hurricane, where sunshine, moisture, heat, radiation, all come into play and would of themselves start the atmosphere into direct lines of motion toward a center of low pressure; whereas the rotation of the earth turns that radial movement into an almost perfect circle. The relative importance is analogous to the influence of gravity on a bowlful of water escaping at the outlet, where the least deviation from symmetry converts the straight line into a circular motion.

Atmospherics is not merely a study of the physics of the atmosphere on the scale of a laboratory experiment; it is a problem in terrestrial physics in which the overpowering influence of the earth considered as a small planet must be fully considered. The lower layers of the atmosphere being resisted by continents and highlands move almost independent of the upper layers that have scarcely any connection with the lower layers, by way

of viscosity or fluid friction, and still less connection due to terrestrial resistances. These upper layers are affected by radiation and absorption, by density, by the attraction of the earth, the moon, and the sun, by the action of solar electrons and cosmic shooting stars, and by the motion of the earth in space, as well as its diurnal rotation. Their motions represent the sum total of astronomical and planetary influences, and they react in a most complicated manner upon the lowest layer of the atmosphere which is under the influence of convective circulation.

The study of the motions of the centers of high and low pressure presented to us every day on these international polar charts of the Northern Hemisphere, may be conducted either by pure analysis, or by graphic methods, or by laboratory experiment. Some suggestions with regard to the latter will be found in the MONTHLY WEATHER REVIEW, December, 1907, volume 35, page 559.

With regard to graphic methods of approaching the problem, I believe that two memoirs, one of which is to appear in the Bulletin Mount Weather Observatory, volume 6, part 5, and the other to appear in this REVIEW, present almost our first practical ideas; their further development and application to our daily weather maps will, we hope, stimulate our best mathematicians to renewed efforts.

With regard to the purely analytical treatment of the problems of atmospherics, the best men, such as Helmholtz, Lord Kelvin, Margules, Lord Rayleigh, Prof. Lamb, and many others, have contributed here and there a mite toward the completion of the work done by Ferrel, but hitherto each has found it impracticable to even attack in its generality that problem which must be solved by some future generation before all doubts and difficulties have been removed.—[C. A.]

PROPOSED DAILY WEATHER MAP FOR THE SOUTHERN HEMISPHERE.

All meteorologists will be interested in a letter from W. Martin Watt, Agricultural Engineer, Salisbury, Rhodesia, who says:

> I am very much obliged for your memorandum covering a copy of the weather map of the United States and the Northern Hemisphere. I find in it a most interesting study, and if it is not asking too much I should be very grateful for an occasional copy.
>
> I trust it will not be long before a similar map is prepared for the Southern Hemisphere, as it would be of immense assistance to forecasters.

This idea of a comprehensive weather map of the world—namely, a map of both Southern and Northern Hemispheres—has been in the minds of most meteorologists for many years. A plan for maps appropriate to their study was published in full in the MONTHLY WEATHER REVIEW for December, 1907, volume 35, page 559. Perhaps the first question to be decided before such maps are prepared will be whether the map of the Southern Hemisphere on a polar projection, should be drawn as seen from the South Pole, or as seen from the North Pole.

The ordinary geographer gives us a map of the Northern Hemisphere as seen from the North Pole and one of the Southern Hemisphere as seen from the South Pole; but all studies in which dynamics enters so intimately as it does in our meteorology require that the point of view should be uniform for both hemispheres, just as it also requires that the observations should be simultaneous with regard to time, and just as the astronomical problems require that same conformability.

The hope that Mr. Watt expresses is perfectly attainable now that the world has at hand the resources offered by wireless telegraphy and ocean cables.

What was supposed to be a mere dream 60 years ago has become an actual reality; no one can foresee what may become a commonplace matter 50 years hence.

The map of the Northern Hemisphere is a matter of coöperation between the northern nations; but these are the powers that have ruled the beginnings of civilization in both Northern and Southern Hemispheres.

A few words from the North and a little financial coöperation would quickly bring to actual realization the daily weather map of the Southern Hemisphere.

The so-called International Meteorological Congress and especially its Permanent Committee may properly take under advisement the project suggested by Mr. Watt.

Africa, Australia and South America, the South Atlantic, the South Pacific and the Indian oceans, certainly need and are worthy of a daily weather map of the Southern Hemisphere. It will pay them and will pay the merchants of the whole world.

The study of the southern map will, indeed, greatly assist the student of the northern map. From pole to pole, around the whole globe and upward to its limits, the atmosphere must be studied as a unit if we would so thoroughly understand its phenomena as to enjoy that accurate long-range forecasting which is to be the privilege of future civilized nations. "Nil desperandum, labor omnia vincit."—[C. A.]

NOTES.

The first structure that the Massachusetts Institute of Technology has erected for its own uses on its site in Cambridge is the new aerodynamic laboratory. The building is finished and the apparatus is in process of installation. The portion of its equipment that is first to be installed is the 4-foot wind tunnel with its accompanying blower. This is of the pattern now in use at the National Physical Laboratory at Teddington, England, which has furnished the plans.

SEISMIC DISTURBANCES IN THE PHILIPPINES.

The Philippine Journal of Science No. 4, published at Manila, August, 1913, contains a careful study of seismic disturbances in the Philippines by M. Saderra Masó and Warren D. Smith. The authors show that seismology and geology combined is a matter of great practical value to humanity and especially to great engineering projects. The major earthquakes are not due to volcanoes, but to splits, cracks, and shifts in the solid rock. They are tectonic and not volcanic. The practical conclusions which the authors draw from their investigations are as follows:

> 1. The fact of the instability of the earth's crust has been proved time and again both by tremendous catastrophes and by laboratory experiments. It has been demonstrated that many of these devastating earth movements take place along definite lines of weakness in the crust. The location and extent of these lines can usually be fairly accurately determined by a geological examination.
>
> 2. The points of intersection of such lines are dangerous as can be shown by an examination of the Province of Calabria in Italy.
>
> 3. Volcanoes are only incidental phenomena, and are results rather than causes. They are usually found to be lined up along some rift line. * * *
>
> 5. Types of structure best suited to Philippine conditions—
>
> (a) Bamboo houses. All parts tied together with rattan.

(b) "Strong" material locally used to distinguish wooden, well-nailed houses from bamboo structures. Floor joists well anchored.

(c) Sand-lime brick tied to steel frame should be cheaper than concrete, and in case of warping walls can be easily removed and new steel put in.

(d) Reinforced concrete, perfectly safe if properly made but expensive and apt to receive permanent warping and fissuring from some earthquakes.

Ordinary brick walls with roof of unanchored tiles make one of the worst possible types of construction as demonstrated at Messina.

6. The necessity of geological examinations of all dam, pipe line, and bridge sites should be emphasized. Tremendous damage * * * to these kinds of engineering structures * * * left [San Francisco] at the mercy of the fires which shortly broke out.

7. The harbors of Cebu, Iloilo, and Zamboanga, owing to their approximating the shape of a funnel or double funnel, are more or less in danger from [earthquake sea waves].

8. Manila Harbor, owing to the comparatively [narrow] entrance and rapidly widening basin, should be entirely safe in the latter respect.

Summary and conclusions.

There is a close relationship between seismic disturbances and geologic structure.

The majority of earthquakes are of tectonic origin, in the Philippines at least.

Volcanoes are secondary phenomena.

The area of greatest seismicity in the archipelago is in the Agusan Valley, Mindanao.

There is a close relationship between the orographic and other geomorphic lines and the lines connecting the principal epicenters in the archipelago.

Seismic disturbances can be studied and disasters can, to a large extent, be avoided.

SECTION III.—FORECASTS.

STORMS AND WARNINGS FOR MARCH.

By EDWARD H. BOWIE, District Forecaster.

[Dated, Washington, Apr. 15, 1914.]

NORTHERN HEMISPHERE PRESSURE.

Alaska.—For the month, as a whole, pressure averaged above normal, being continuously so during the latter half. One of the most persistent high-pressure areas noted since the beginning of observations from the Aleutian Islands obtained over that region from the 23d through the end of the month, not once during the period mentioned did the pressure fall below 30.50 inches. Lows occurred about the 3d, 8th, and 14th; and highs about the 5th–6th, 9th–11th, 16th–17th, 19th–20th, 24th, 27th, 29th, and last day of the month.

Honolulu.—Pressure averaged below normal for the month. Highs occurred from 1st to 4th and during the 12th and 13th, while during the remainder of the month pressure was below normal. Lows occurred on the 8th–9th, 17th, 21st–22d, 24th–25th, and on the 29th. Pressure conditions over this area were the reverse of conditions over Alaska, all the larger fluctuations of pressure in one area showing as inversions in the other.

Iceland.—Pressure averaged below normal, being continuously below from the 2d to 7th, 12th to 21st, and during the 23d and 24th. The only marked high area of the month prevailed from the 26th to 31st, its crest occurring on the 28th, with a pressure reading of 30.40 inches. Lows occurred on the 2d–3d, 4th–5th, 6th, 12th–13th, 15th, 17th–18th, 20th, and 24th; and highs on the 8th, 10th–11th, 21st–22d, and 28th. Over the British Isles and western Europe pressure was decidedly low during almost the entire month, especially from the 15th to 27th. On the 14th heavy gales caused considerable damage to property and shipping in Ireland and during the 17th and 18th telegraph service in France and Germany suffered a good deal of interruption due to high winds.

Azores.—Pressure was decidedly above the seasonal average, being continuously above except during the 8th and the last six days of the month. Lows occurred on the 8th, 12th, 27th, and 29th–30th; and highs on the 1st–4th, 10th, 14th–17th, and 20th–21st.

Siberia.—During the greater part of the month fluctuations of pressure were moderate in character. Over the southern portion of this area pressure was slightly below the seasonal average, while over the remainder of the territory pressure averaged slightly above the normal. The most important lows occurred about the 3d–5th, 15th–16th, 18th, 20th–21st, and during the last week of the month. At Odessa and Astrakhan pressure was decidedly below the average on the 14th and during the last six days of the month. According to newspaper dispatches the storm of the 14th caused considerable damage in the region around Astrakhan due to the high winds and heavy rains.

PRESSURE OVER THE UNITED STATES.

In the United States the month opened with a severe storm off the North Carolina coast which was causing winds of moderate character in Coast States and severe gales off the middle Atlantic coast as indicated in the following vessel reports: In latitude 33°, longitude 72½°, one vessel reported 74 miles per hour from the west; and in latitude 36°, longitude 72½°, another vessel reported 64 miles per hour from the southeast. By the evening of the 1st the storm had advanced to the western end of Long Island with the lowest pressure reading at New Haven, Conn., of 28.25 inches, one of the lowest ever reported in the United States. Winds had increased to storm force along the middle and north Atlantic coasts, a maximum velocity of 85 miles per hour being reported from Nantucket. During the succeeding 12 hours the storm remained nearly stationary and pressure rose slightly at its center. On the morning of the 3d the center was off the Maine coast and on the following morning over the Grand Banks. The high winds did not moderate until the 4th. This storm was one of the most severe from the standpoint of wind velocity that has visited the Atlantic seaboard for years, the persistence of the high winds for a period of about three days being most unusual. Heavy snows were reported in connection with this disturbance in eastern Pennsylvania, New Jersey and eastern New York, causing serious delays to railway traffic and to telephone and telegraph communication. Southeast storm warnings were issued on the evening of February 28 from Fortress Monroe to Eastport, with the information that fresh shifting gales were to be expected along the middle Atlantic and New England coasts Sunday morning (Mar. 1). On the morning of March 1 the following message was disseminated to Atlantic coast ports:

> Storm of marked intensity off Hatteras moving north. High shifting winds will become northwest gales to-night with probably rain turning to snow and much colder weather. Advise shipping to remain in port.

The warnings for gales were again repeated on the 2d.

The high pressure area that was over the eastern Plains States at the beginning of the month advanced slowly eastward to the Ohio Valley with decreasing intensity after which it disintegrated. It caused frosts and freezing temperatures in the East Gulf, portions of the South Atlantic States and in Florida on the 3d, the occurrence of which in the main were successfully forecast. This high caused sweeping changes to colder weather throughout the East Gulf and South Atlantic States, a number of low temperature records in Virginia, the Carolinas and Georgia for the month of March being broken.

The next disturbance to cross the country developed over the southern Rocky Mountain region on the 2d in the trough of a Canadian Northwest low that was central at Edmonton on the morning of the 1st. The Rocky Mountain storm passed thence southeastward to the mouth of the Rio Grande by the evening of the 3d, the

showers attending it being confined to the west Gulf States. From the Texas coast it moved across the Gulf States and up the Atlantic coast with increasing intensity causing showers in Gulf and Atlantic coast States. On the morning of the 6th storm warnings were ordered for the New England coast and high winds occurred as indicated.

On the evening of the 3d a disturbance appeared in the Province of Alberta and passed slowly southeastward to the Ohio Valley by the morning of the 7th, causing scattered showers over the Plains States, the middle and upper Mississippi Valley, the Ohio Valley and the Lake region. On the morning of the 3d storm warnings were issued for the north Pacific coast and high winds occurred as forecast in the advices.

On the north Pacific coast pressure remained high from the 1st to 5th and on the morning of the 6th an offshoot from this high pressure area was central over Texas, the northern center however was central over Idaho. The latter passed over the northern route with decreasing intensity, while the Texas center moved eastward across the Gulf States causing frosts on the 8th in the Gulf States, on the 9th in the East Gulf and portions of the South Atlantic States, and in Florida, and on the 10th in portions of Florida and the South Atlantic States. Most of the frosts mentioned were foretold in advices issued previously to their occurrence.

The next disturbance to cross the country appeared in the Canadian Northwest on the morning of the 8th, and passed thence south-southeastward to the Texas Panhandle by the 10th. From this point it passed eastward across the Gulf States to the Atlantic Ocean causing showers over the South Atlantic and Gulf States and high winds on the west Gulf coast, warnings of which were issued on the evening of the 10th.

This disturbance was followed by a high pressure area that made its appearance over Alberta on the morning of the 9th and passed south-southeastward following much the same course as the low immediately preceding it, and causing heavy and killing frosts over portions of the West Gulf States on the 12th and over the Gulf and South Atlantic States again on the 13th and 14th. It had passed off the South Atlantic coast by the morning of the 15th leaving however a slight high pressure area over Georgia on that morning, frosts being again reported in the East Gulf and South Atlantic States. With the exception of the frosts on the 15th, their occurrence was successfully indicated.

At Turks Island, West Indies, on the morning of the 14th the pressure was 0.02 inch lower than on the previous observation and the weather had become cloudy. On the following morning the wind had shifted from an easterly quarter to westerly and the pressure had fallen to 29.90 inches indicating the existence of a disturbance to the northward or northeastward. On the morning of the 16th the pressure at Turks Island had risen to 29.94 inches and the wind was north, while at Hamilton, Bermuda, the pressure had fallen 0.34 inch to 29.90 with the wind northeast and raining. At the evening observation of that date the barometer reading at Bermuda was 29.40 inches, wind southeast and weather raining. On the following morning the pressure had risen 0.36 inch and the wind had shifted to south. From these facts it may reasonably be supposed that the storm developed somewhere northeast of Turks Island and passed northward on a course that carried it near and to the west of the Bermudas and then probably recurved to the northeastward, as no evidence of it was observable on the North Atlantic coast nor along the coasts of the Canadian Maritime Provinces.

A disturbance appeared over northern Saskatchewan on the evening of the 14th, and passed over a northern course to the St. Lawrence Valley by the morning of the 17th, causing light showers in the northern Lake region and high winds in the northern upper Lake region. An offshoot from this storm appeared on the 17th over northern Lake Michigan and on the evening of that date two centers were noted, one over Lake Erie and the other over northwestern South Carolina. On the evening of the 17th storm warnings were issued for the middle Atlantic and New England coasts and were continued from Sandy Hook to Eastport on the following day. High winds occurred as forecast. The South Carolina disturbance developed increased energy and passing up the coast was central on the morning of the 19th over northern Maine, with pressure reading 29.34 inches at Greenville, high winds being reported from Delaware Breakwater northward. The storm thence passed northeastward to Newfoundland by the morning of the 21st, with lowest pressure reading at St. Johns, 28.82 inches.

A high pressure area appeared over Saskatchewan on the morning of the 17th and by the following morning had moved to Manitoba, with a tongue of high pressure extending southward through the Mississippi Valley. This tongue of high pressure swung eastward following the passage up the Atlantic coast of the low immediately before mentioned causing light frosts on the 19th in the South Atlantic States. The main portion of the high seemed to lag and was later augmented by another high that came from the northwest Canadian Provinces on the 18th.

During the retardation of this high and preceding the coming of the second high a low appeared over northern Wyoming on the evening of the 17th which during the 36 hours following passed to the west Gulf coast, causing rain and snows from the Rocky Mountains through the Plains, southern Slope and West Gulf States. By the morning of the 20th it was over the coast line of North Carolina, whence it passed east-northeastward to the ocean. Precipitation was quite general from the Mississippi Valley eastward, except in northern districts. From the 17th to 19th, the highest temperatures recorded in the month of March were reported from points in California.

The high-pressure area before referred to as being augmented by a high-pressure area from the northwest Canadian Provinces during the 18th was central on the morning of the 19th over the Plains States. Cold-wave warnings were issued on the 18th for Kansas, western South Dakota, southern Wyoming, and northeastern Colorado. On the morning of the 20th the high extended from the upper Lake region to the West Gulf States, killing frosts and freezing temperatures being reported in the northern portion of the latter district. By the morning of the 22d the high had passed off the Middle Atlantic coast. The frosts in the West Gulf States above mentioned were indicated in warnings issued on the 19th. The passage of this high was attended by temperatures much below the seasonal average, particularly in the region from the Mississippi Valley to the Rocky Mountains.

Following the passage of this high-pressure area there was a slight reaction to lower pressure, but readings below 30.00 inches were not reported until the morning of the 22d, when there was a weak disturbance off Hatteras with pressure reading at that station of 29.90 inches and another over Minnesota with pressure reading at Duluth of 29.88 inches. The Hatteras low passed rapidly up the

coast with increased intensity, while the Minnesota disturbance passed east-southeastward to the Ohio Valley with decreasing intensity by the morning of the 23d.

A pressure reading of 30.94 inches was reported at Edmonton, Alberta, on the morning of the 20th, with temperature readings near 0° F. in the Canadian Northwest and cold-wave warnings were disseminated for portions of the Plains and southern Slope States. The high passed thence southward to the West Gulf States by the morning of the 22d, causing frosts on that morning over the West Gulf and portions of the East Gulf States. On the morning of the 23d it had advanced to northwestern Florida, and frosts were reported throughout the Gulf and South Atlantic States, warnings of which were previously issued. On the 24th the high was central over North Carolina and frosts were again reported in the South Atlantic and East Gulf States. The high-pressure area passed northeastward to the ocean.

The next disturbance to cross the country was undoubtedly of north Pacific origin. It first appeared as a definite center over Idaho on the evening of the 22d, passing southeastward to Colorado by the 24th and thence northeastward during the following two days to the St. Lawrence Valley. It caused showers and thunderstorms over an area extending from Kansas and Nebraska northeastward to the St. Lawrence Valley. Another low followed, being central near Edmonton, on the morning of the 24th, and passing thence southeastward to Colorado during the next 36 hours. A secondary storm that was over New Mexico on the evening of the 25th passed eastward and up the Ohio Valley until on the morning of the 28th it was central over southwestern Pennsylvania. It was thence forced southward to North Carolina on the evening of that date by a high-pressure area to the northward and, later developing intensity, passed northeastward up the Atlantic coast, being central at the last of the month over the Canadian Maritime Provinces. These two storms caused scattered showers and thunderstorms over most of the country from the Plains States eastward. On the evening of the 28th storm warnings were issued for the Atlantic coast from Delaware Breakwater to Nantucket and continued on the morning of the 29th from Nantucket to Bridgeport, Conn., and high winds occurred over the areas indicated.

On the 26th pressure became high over Saskatchewan and on the following morning a high center was over western Ontario with temperatures below zero from Saskatchewan to western Ontario. By the morning of the 28th the high area was over eastern Ontario, whence it passed eastward to the ocean during the next 48 hours. Another high area appeared over eastern Manitoba on the 29th and on the morning of the last day of the month was over Ontario and by the evening of that date on the southern New England coast.

Lows of minor character continued to develop over the southern Rocky Mountain Region, which caused showers and thunderstorms as they advanced eastward to the Ohio Valley. At the last of the month low-pressure areas were over Oklahoma, the mouth of the Rio Grande, and Saskatchewan, and pressure was high over New England and the Middle Atlantic coast.

Pressure was below normal on the extreme north Pacific coast from the evening of the 25th until the 28th, on the morning of which latter date pressure readings showed a fall from the preceding observation, and storm warnings were issued for the north Pacific coast. These warnings were continued on the 29th and 30th and high winds occurred over the districts indicated in the warnings.

SOLAR INFLUENCES?

There is a familiar authority, formerly very active in Virginia, who taught the truth of the text in the Book of Joshua: " 'Sun, stand thou still' * * * And the sun stood still," whereas, in the ancient scripture this phrase is a quotation from a bit of sublime poetry, equal in its impressiveness to the blank verse of Milton's "Paradise Lost."

Most modern writers accept the fact that the ancient authors were writing poetry, not science, whereas the modern author of "The central law of the weather" seems to accept this quotation from Holy Scripture as the basis of his system of local weather forecasts.

Of course, the study of the solar atmosphere and its phenomena is a very important part of modern astronomy, and we may believe that it is related to the study of modern meteorology, but we have not as yet seen that any meteorologists have been able to forecast at long range coming weather changes on the earth by means of the spots on the sun. Nor is it apparent that there is any physical reason why we should expect to be able to do so.—[C. A.]

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, MARCH, 1914.

By ALFRED J. HENRY, Professor of Meteorology, in charge River and Flood Division.

In the Mississippi watershed there was no time during March that a flood threatened, and at this writing, April 19, it seems probable that, barring the occurrence of torrential rains in the immediate future, the annual spring rise of 1914 in the Mississippi will not assume the importance of a flood.

A short period of high temperature that culminated on the 16th caused the ice-bound portion of the river, St. Paul to Davenport, to open on very moderate stages on that date. The last of the ice in Lake Pepin did not disappear, however, until about 30 days later. The river below Cairo fell slowly from the 1st to the 13th, and thereafter rose very slowly until the end of the month, when the gage on the Ohio at Cairo read 22.4 feet, 22.6 feet below the flood stage. Below Cairo the river was at moderate stages during the month.

Both the Missouri and the Ohio were also at moderate stages during the month.

Flood stages were reached in the Pedee and Waccamaw of South Carolina, the Pearl of Mississippi, and the Black Warrior of Alabama, due to heavy rains locally over the respective watersheds, but in no case was the flood destructive in character.

A second period of high temperatures about the end of the month, with rain on the 28th and again on the 30th, caused flood conditions to prevail in the rivers of New England and the northern portion of the Middle Atlantic States.

The Connecticut passed the flood stage at Hartford, 16 feet, on the 29th, and crested at 18 feet on the same day. The Hudson at Albany crested at 16 feet on the 29th, flood stage 12 feet. The Susquehanna passed the flood stage, 14 feet, at Binghamton on the 28th, and crested at 18.5 feet on the 29th.

The following crest stages were recorded on the Susquehanna at points below Binghamton: Towanda 20.2 feet on the 28th, flood stage 16 feet; Wilkes-Barre 28.3 feet on the 29th, flood stage 20 feet; Selinsgrove 16 feet on the 30th, flood stage 17 feet; Harrisburg 18.2 feet on the 29th, flood stage 17 feet. The above floods were accurately forecast by Weather Bureau officials in the respective districts.

MOUNTAIN SNOWFALL, MARCH, 1914.

California.—The snowfall during March was very light, but there is a large amount of well-packed snow in the higher mountains which has a water equivalent of from 40 to 50 per cent and insures an ample supply of water for the coming season.—*G. H. Willson, Local Forecaster.*

Oregon.—Owing to unseasonably high temperatures during the greater part of March the precipitation was in the form of rain, and but little snowfall was recorded below the higher altitudes, and, except at a few scattered stations in northeastern and southwestern counties, small amounts of snow were reported throughout the section

Compared with last year there was generally less snow in all districts, the only exceptions being at one station in the Siskiyou Range and at two in the Blue Mountains, where there were somewhat greater depths reported than at the close of March of the previous year.

Compared with the normal there is less snow than usual at this time of year, but that remaining is well packed.—*E. A. Beals, District Forecaster.*

Washington.—The snowfall for the month was much less than the average for March in nearly all localities. It was from 5 to 39 inches at stations on the western slope of the Cascades, from 1 to 47 inches on the eastern slope, and from 1 to 13 inches on the foothills and slopes bordering the Blue Mountains.

The first three weeks of the month averaged 5 or more degrees above the normal temperature for the time of year, and consequently the snow covering disappeared early on all but the higher slopes and summits, in timbered areas, in the gulches, and on cold northern slopes.

Such limited density tests as were made at moderate elevations show the water equivalent to be high.—*G. N. Salisbury, Section Director.*

Montana.—The month of March brought very little change in the snow conditions in the mountains. The snowfall for the month was below normal in most sections, and the mild temperatures that prevailed until about the 20th somewhat reduced the amount remaining from previous months. In the valleys and foothills the ground was generally bare at the end of the month, notwithstanding most of the month's snow fell during the last 10 days.

Owing to the absence of frost in the ground there was comparatively little surface runoff, the percentage of loss from this source being much smaller than in seasons of normal snow accumulation. The late flow of water which is of most importance in irrigation depends in large measure upon the water thus taken up by the soil over the entire surface of the watershed rather than upon the surface supply from melting snows in the high mountains. The effect of the deficiency in the snow accumulation will, therefore, probably be more noticeable in the flood stages of the late spring and early summer than in the later stages.—*R. F. Young, Section Director.*

Wyoming.—Reports from various sources show the average fall of snow for the State to be 7.4 inches, 4 inches below normal. The only watershed over which conditions have improved to a marked degree is that of the Tongue River, where a normal amount of snow covers the ground, promising an average flow of water for the summer. Depths of snow on the Powder River watershed increased appreciably during the month, but less than a normal flow of water may be expected. Accumulated depths on the watersheds of the North Platte, Green, and Snake Rivers promise sufficient water for the approaching season, but conditions on the headwaters of the Sweetwater, a tributary of the North Platte, are much less promising than at the close of February. Reports from the watersheds of the Big Horn, Cheyenne, and Yellowstone vary greatly, although it is thought that the flow of water will be little below normal, espe-

cially as depths of snow have increased substantially during the general snowstorm occurring the first week in April.—*R. Q. Grant, Section Director.*

South Dakota.—The average snowfall in the elevated regions of South Dakota; that is, the greater portion of the Black Hills district of the State, was 7 inches. The largest monthly amount recorded was 23 inches, at Harvey's ranch (P. O. Hanna), Lawrence County; the least 0.2 inch at Hermosa, Custer County. There was none remaining on the ground on either the 15th or 31st of the month, except in the gulches in the timber. Some of the snow melted as it fell, or soon after, and thawing weather with local showers near the close of the month aided in its disappearance.—*S. W. Glenn, Section Director.*

Nevada.—There was scarcely any snow or precipitation in the Truckee, Carson, and Walker Basins during March. The average for 12 stations in the Humboldt Basin was 0.43 of an inch, which was only about one-third of the normal. This is representative of the northern portion of the State.

At the Lake Tahoe level there were about 39 inches of dense snow at the end of the month, and it increased in depth from that point to 137 inches at the 7,400-foot level, just south of Ward Peak. There were from 96 to 120 inches near Grass and Luceil Lakes at an elevation of about 8,000 feet. East of Lake Tahoe there were about 84 inches at 8,000 feet. In the Carson and Walker Basins on nearly all northwest, north, and northeast slopes, above 9,000 feet, there were over 260 inches of snow at the end of March.—*H. S. Cole, Section Director.*

Arizona.—March was a warm, dry month in the eastern and northern mountain districts, and there was a general decrease in the depth of stored snow.

In the White Mountains, where a survey of a representative area was made, March 21 to 27, the snow on the north slopes ranged from a trace at the 8,000-foot level to about 50 inches at the 10,000-foot, while on the south slopes there was but little snow below 9,000 feet, and at 10,000 feet the depth was about 15 inches. The extensive flats of high elevation, situated along the Salt-Little Colorado Divide, held from 20 to 30 inches of snow. The average of a large number of density measurements gave an equivalent of 0.33 inch of water for 1 inch of snow.

Reports indicate that the snow conditions on the Blue, Graham, and San Francisco Ranges are about the same as in the White Mountains, while on the Chiricahuas the depths are somewhat less. There is little or no snow left in the Tonto and East Verde watersheds. Drifts from 2 to 4 feet deep remain on the plateaus north of the Colorado River. A few inches remain on the Huachuca Mountains.—*Robert R. Briggs, Section Director.*

New Mexico.—March averaged much below the normal in precipitation, although the snowfall was parctically normal, owing to heavy snow in certain central and northern mountain districts, notably east of the Rio Grande. For the State as a whole the eastern slopes were most favored.

The average snowfall was 3.8 inches, or about normal, giving a seasonal fall of 26 inches, which is slightly in excess of the normal, owing to the large excess that occurred in December, 1913.—*Charles E. Linney, Section Director.*

Colorado.—The snowfall during March was less than the normal in almost all parts of the mountain region, making the third month in succession with relatively light amounts. Storms were not lacking, but precipitation was general only during the last three days of the month.

On the middle drainage of the South Platte and in the region drained by the southern tributaries of the Arkansas somewhat more than the normal snowfall occurred, but in the rest of the drainage area of these streams a deficiency was general. Marked deficiencies occurred throughout the region drained by the Rio Grande, and and over the greater part of the Grand, Gunnison, and San Juan watersheds.

The average depths of snow on the ground on the different watersheds at the end of the month do not differ materially from the depths on corresponding date a year ago; the water equivalent, however, is greater.—*F. H. Brandenburg, District Forecaster.*

POSSIBILITY OF RECURRENCE OF THE FLOODS OF MARCH, 1913.

By J. WARREN SMITH, Professor of Meteorology.

[Dated Weather Bureau, Columbus, Ohio, March 12, 1914.]

[Abstract of a paper read March 11, 1914, at the Thirty-fifth annual meeting of the Ohio Engineering Society, held at Columbus, Ohio.]

During the past 20 years the number of coöperative stations in Ohio reporting rainfall has varied but little and has been slightly over 100 in number.

The number of times that excessive rains have occurred at these different points has been tabulated and the summary appears in Table 1.

This table shows that while the number of stations reporting 2.5 inches in 24 hours in 1913 was less than twice as many as reported this amount in 1896 and 1897, and only just twice as many as in 1911, the number reporting 5.0 inches or more in 96 hours in 1913 was more than in all of the other 19 years put together.

In March, 1913, the number reporting 5.0 inches or more in 96 hours was 73, while during all of the other months of the 20 years together the number was only 69.

In October, 1910, there was a very heavy and extended rainfall in Ohio that gave 2.5 inches or more in 24 hours at 35 stations, 3.0 inches or more in 48 hours at 49 stations, and 4.0 inches or more in 72 hours at 31 stations; or about half as many as occurred in March, 1913. But in October, 1910, there were only 3 cases of 4.0 inches or more in 24 hours, as compared with 13 in March, 1913, and only 3 stations reporting 5.0 inches or more in 96 hours, as compared with 73 reporting this amount in March, 1913.

It is only when one begins to tabulate the facts in this way that the statement can be understood that when the extent of the territory involved and the sequence of the storms is considered, no previous record exists which, in this section of the country, is in any way comparable with the rainfall of March 23-27, 1913.

The greatest monthly rainfall for the State of Ohio during the past 60 years was 9.67 inches, in September, 1866. The next greatest monthly average was 8.40 inches, in March, 1913. The daily records for such stations as were available in 1866 show, however, that during that month the rainfall was distributed more through the month and that large monthly falls were due to a number of scattered heavy rainfalls.

A careful summary of the rainfall data in Ohio for March, 1913, shows that the average rainfall from the 23d to 27th, inclusive, was as follows:

	Inches.
Over the Little Miami watershed	7.5
Over the Sandusky watershed	8.2
Over the Scioto watershed	8.7
Over the Great Miami watershed above Dayton	8.6
Over the Muskingum watershed above Zanesville	6.9

TABLE 1.—*Number of stations in Ohio reporting excessive rainfall in the year indicated.*

Year.	2.5 inches or more in 24 hours.	4 inches or more in 24 hours.	3 inches or more in 48 hours.	4 inches or more in 72 hours.	5 inches or more in 96 hours.	10 inches or more in 1 month.
1894	15	2	5	1	0	0
1895	13	0	10	0	0	0
1896	58	6	52	27	13	17
1897	59	7	32	13	5	3
1898	38	4	38	17	11	4
1899	20	5	7	0	0	0
1900	22	0	11	0	0	0
1901	45	5	38	25	11	2
1902	34	4	55	28	4	6
1903	34	5	28	10	4	0
1904	34	2	40	16	3	0
1905	45	5	37	8	3	1
1906	26	2	17	5	2	2
1907	43	5	48	19	2	3
1908	23	1	10	0	0	0
1909	45	8	25	7	0	1
1910	49	3	65	34	6	0
1911	54	3	18	4	0	0
1912	45	1	24	6	0	0
1913	108	21	106	84	78	31
Sums	810	89	666	304	142	70
Means	40	4	33	15	7	4

Probability of similar heavy rainfalls in future.

The preceding statements show that while the rainfall in March, 1913, was unprecedented in duration, intensity, and area covered so far as the central part of the United States is concerned, yet the atmospheric conditions that produced the rainfall were apparently not abnormal.

And further, that there is nothing to prevent the same atmospheric conditions recurring any time, and hence no good grounds for not saying that we may have the same or a more severe rainfall at any time in the future.

On the other hand there seems no basis whatever for the statement in the local press of February 10, accredited to the president of the National Drainage Congress, that—

> There is a scientific reason to expect a flood this year that may be as disastrous as that of 1913.

The newspaper clipping indicates that the reason for this statement is the fact that there was a deficiency in rainfall in January in the Mississippi and Ohio valleys, and thus:

> An abnormal rainfall equal to that of 1913 is to be expected in order to bring the precipitation up to normal, according to the records of the drainage commission.

It is true that there was a deficiency in rainfall in January in most of the Mississippi and Ohio valleys and that this deficiency amounted to over 4 inches in the vicinity of Vicksburg, Miss., but it is not true that similar deficiencies are immediately followed by excessive precipitation or that a monthly rainfall above the normal will necessarily cause floods.

A careful correlation has been made between the rainfall in January and that in March in Ohio, during the past 60 years, and this shows a correlation coefficient of 0.24. This means that when the rainfall is deficient in January it is most apt to be deficient in March also, and when the rainfall is in excess in January it is most apt to be wet in March.

And not only this, but in the past 60 years there never have been but two years when a very dry January in Ohio has been followed by a rainfall of more than 1 inch above the normal in either February, March, or April in Ohio. And further, during the past 50 years a very dry January has been followed by rainfall enough in either February, March, or April to cause even one day of flood at Cincinnati only four times.

The January just past had an average rainfall almost 1 inch below the normal in Ohio, but instead of this being a condition favorable for later floods, as stated in the newspaper article referred to, it is just the opposite. Hence the probability of floods in Ohio this spring is much less than if the rainfall in January had been above the normal.

The heaviest rainfall in one day in Ohio that has ever been recorded was 7.4 inches at Toboso, in northeastern Licking County, on the night of July 13, 1913. This storm was very severe, and while it gave heavier 12- and 24-hour rainfalls at a few places than occurred in the March storm, it was not of so large an area and was not followed by successive downpours.

It shows, however, as do other storms that might be cited, that there is nothing to prevent a recurrence of the heavy rainfall of last March in any section of the country. On the other hand the fact that no such extended and continuous rainfall has occurred before in Ohio during the past 60 years at least, and probably not during the past 100 years, must lead to the conclusion that the chances are against a repetition of such a rain within the next 60 or 100 years.

Probability of similar flood damage with same rainfall.

The ground was not frozen at the beginning of the heavy rainfall in March, 1913, but sufficient rain had fallen only two days before to thoroughly saturate the soil, so that when the heavy rain began the streams felt its influence immediately. Floods will occur when there is an excessive rainfall or with a combination of heavy rainfall and melting snow.

The encroachments on the streams, both in the matter of fills and in low and short bridges, intensified the flood damage at places on all of the streams, but the cause of the unprecedented high water was the unprecedented rainfall and nothing else.

In WEATHER BUREAU BULLETIN No. 40 the writer has correlated the rainfall over the Ohio watershed above Cincinnati with the river-gage readings at that place for the 50 years from 1861 to 1910, inclusive. This shows that, with the same rainfall, the tendency for high water and floods is not quite so great during the last half of that period as during the first half. A tabulation of the rainfall and river heights for each 10 years shows without question that floods are not increasing at Cincinnati with the same rainfall.

The correlation of low water and rainfall in this bulletin shows that, with the same rainfall, the number of days with the river below 10 feet will not be so great now as was experienced 30 or 40 years ago.

Conclusions.

The conclusions drawn from this paper and other studies regarding the rainfall and stream flow are:

1. Excessive rainfalls in the interior of the United States are due to unstable atmospheric conditions that accompany some low-pressure areas as they move across the country from west to east.

2. Usually these conditions of heavy rain are of short duration and comparatively small area and progress eastward with the depression. Occasionally, however, when the depression stands nearly still or when a southwest-

northeast trough forms and two or more disturbances follow each other rapidly, each accompanied by heavy rain, the area of excessive rain is enlarged, and the total rainfall causes serious floods.

3. Floods are due to excessive rainfall. While the draining of the swamps, the tiling of the fields, and the cutting of the forests may have some slight effect upon the intensity of the flood, all these things are of far secondary importance when compared with the rainfall.

The combination of the meteorological factors which caused the flood of March, 1913, may recur any year, but the probability of a repetition is not great. It is true that the duration and area of the intense rainfall in last March never has been approached before in the history of meteorological records in Ohio and probably not in any other district in this part of the country.

The tendency for excessive rains to occur is not growing greater. Neither are floods growing more frequent or are they worse with the same rainfall.

SECTION V.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

By C. FITZHUGH TALMAN, Junior Professor, in charge of Library.

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Die Messung der Niederschlagselektrizität durch das Galvanometer. Kiel. 1913. 41 p. 2 pls. 8°. (Inaug.-diss.—Kiel)

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Netherlands. K. Meteorologisch instituut.
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Nürnberg. Wetterwarte.
Das Wetter zu Nürnberg im Jahre 1913, von [Kaspar] Rudel. Nürnberg. 1914. 31 p. 8°.

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Pozděna, Rud.
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Fiume napfénytartamának viszonyai 1902–1912. [Duration of sunshine in Fiume, 1902–1912.] Budapest. 1913. 15 p. 4°. (*Különlenyomat* "A tenger" 3. évfolyam, 4. füzetéből.)
"A Magyarországi párolgásmegfigyelésekről. [Evaporation conditions in Hungary.] Budapest. 1913. 19 p. pl. 4°. (*Különlenymat* "A vízügyi közlemények" 1913. évi 5. füzetéből.)

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RECENT PAPERS BEARING ON METEOROLOGY.

C. FITZHUGH TALMAN, Junior Professor, in charge of Library.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American geographical society. Bulletin. New York. v. 46. 1914.
Henry, Alfred J. Secular variation of precipitation in the United States. p. 192–201. (March.)
Arctowski, Henryk. The annual variation of atmospheric pressure in the United States. p. 265–281. (April.)

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Eckersley, T. L. The energy available for sun power plants. p. 47–48.

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Meteorological influences on radio-telegraphy. p. 854–855.

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Wooldridge, F. V. The bactericidal, deodorizing and physiological effects of ozone. p. 778–779. (April 9.)
Hinds, Julian. Wind pressure on chimneys. p. 922–923. (April 23.)
A conference on the snow-removal problem. p. 934–935. (April 23.)

Geographical journal. London. v. 43. April, 1914.
Kropotkin, P. On the desiccation of Eurasia and some general aspects of desiccation. p. 451–459.

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Eredia, Filippo. Distribution of drought. p. 325–329.

Journal of geography. Madison. v. 12. April, 1914.

Williams, F. E. The climate of Wisconsin. p. 232–234.

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Nagaoka, H. Note on a theory of thunderstorms. p. 228–231.

Meteorological society of Japan. Journal. Tokyo. 33d year. March, 1914.

Fuziwhara, S. The horizontal rainbow. p. 5–13.

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Carse, G. A. Atmospheric electric potential results at Edinburgh during 1912. p. 317–332.

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Shaw, W[illiam] N[apier]. Principia atmospherica: a study of the circulation of the atmosphere. p. 77–112. [See Moly. w. rev., Ap., 1914.]

Scientific American. New York. v. 110. April 11, 1914.

The composition of air and rain water in the Antarctic. p. 304. [Abstract.]

Scientific American supplement. New York. v. 77. April 4, 1914.

McAdie, Alexander [G.] Some facts and problems regarding our atmosphere. What soundings have taught and what still remains to be learnt. p. 210–211.

Scottish meteorological society. Journal. Edinburgh. v. 16. no. 30. 1912.

Miller, N. H. J. The composition of rain water collected in the Hebrides and in Iceland. p. 141–158. [Includes statistics of nitrogen in rain obtained by previous observers at a large number of places throughout the world.]

Fairgrieve, M. McCallum. A possible two-hourly period in the diurnal variation of the barometer. p. 158–166.

Shaw, W[illiam] N[apier]. Upper-air calculus and the British soundings during the international week (May 5–10) 1913. p. 167–178.

Shaw, W[illiam] N[apier]. On seasons and crops in the east of England. p. 179–183.

Watt, Andrew. On the correlation of weather and crops in the east of Scotland. p. 184–187.

Symons's meteorological magazine. London. v. 49. 1914.

Aitken, John. The Stevenson screen. p. 35–36. (March.)

Watson, William Henry. Origin of the Snowden gauge. p. 37. (March.)

M., R. C. Sir John Murray, K. C. B., F. R. S. 1841–1914. p. 45–47. (April.) [With portrait.]

The Hon. Francis Albert Rollo Russell. 1849–1914. p. 47–48. (April.)

Solyom, Herbert L. The rainfall of southern South America. p. 53–55. (April.)

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Capus, Guillaume. La valeur économique des pluies tropicales. p. 109–126.

Schokalsky, [Jules] de. Une dénivellation récente et brusque du niveau de la mer Caspienne. p. 151–159.

Anfossi, G[iovanni]. L'effet utile des précipitations sur l'alimentation des cours d'eau. p. 168–171.

Archives des sciences physiques et naturelles. Genève. t. 37. 1914.

Lecoultre, Fridtjof. Contribution à l'étude de la grêle. p. 172–174. (15 fév.) [Description of a peculiar hailstorm.]

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Astronomie. Paris. 28. année. Avril 1914.

Renaudot, G. L'éruption de Sakurajima. Les volcans du Japon et leur action dans l'atmosphère. p. 178–184.

Cosmos. Paris. 63. année. 29 janvier 1914.

Nodon, A. Description d'un baromètre et d'un thermomètre datant de deux siècles. p. 131–132.

Nature. Paris. 42. année. 21 mars 1914.

Gouchet, É[mile]. Les aurores polaires et le cinématographe. p. 282–284.

Société météorologique de France. Annuaire. Paris. 62. année. Mars 1914.

Rey, J. J. Sur quelques apparences de la foudre pendant les orages. p. 65–74.

Angot, A[lfred]. Les paragrêles électriques. p. 82–85. [Above, p. 166.]

Raymond, G. Nuages neigeux passant devant le soleil. p. 88–89.

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Braak, C[ornelis]. Die tägliche Temperaturschwankung der Luft in verschiedenen Höhen über dem tropischen Meere. p. 141–152.

Schmauss, A[ugust]. Die Substratosphäre. p. 153–164.

Dietzius, Robert. Vertikale Luftströmungen an der Grenze zwischen Troposphäre und Stratosphäre. p. 165–172.

Wigand, Albert, & Lutze, Georg. Bericht über eine wissenschaftliche Freiballonfahrt bis 9425m. Höhe. p. 173–186.

Deutsche Luftfahrer Zeitschrift. Berlin. 18. Jahrgang. 15. April 1914.

Béjeuhr. Richard Assmann. p. 173. [Announcement of retirement; brief biography.]

Schreiber, Paul. Zur Praxis der Gummipiloten. p. 178–179.

Schütze, Alfred. Ein neuer Theodolit mit Schnellablesung, insbesondere für Pilotballon-Beobachtungen. p. 179.

Meteorologische Zeitschrift. Braunschweig. Band 31. März 1914.

Wegener, Kurt. Über die Wirkung des Klimas auf den Menschen. p. 97–104.

Exner, Felix M. Über monatliche Witterungsanomalien auf der nördlichen Erdhälfte im Winter. p. 104–109.

Hennig, Robert. Eintritt und Ende einer Frostperiode in Süddeutschland mit besonderer Berücksichtigung der geographischen Lage und der aerologischen Messungen. p. 109–120.

Barkow, E. Vorläufiger Bericht über die meteorologischen Beobachtungen der deutschen antarctischen Expedition 1911–1912. p. 120–126.

Hann, J[ulius] v. Temperatur in dem Barometermaximum von Januar-Februar 1914. p. 133–137.

Woeikof, A[leksandr] [Ivanovich]. Temperatur und Feuchtigkeit in Berg und Tal in Amurland. p. 140–143.

H[ann], J[ulius] v. W. N. Shaw über die Änderung der Druckdifferenzen zwischen Hoch und Niederdruckgebieten mit der Höhe. p. 143–144. [Above, p. 151.]

Rethly, A[nton]. Verdunstungsmessungen in Ungarn. p. 144–145. Results for 13 stations, 1901–1912.

Hochsteiner, O. Über den Einfluss von Druck- und Temperaturänderungen auf die Bewölkung in den deutschen Mittelgebirgen. p. 147–149.

Everling, E. Beobachtung und Theorie der durch Reflexion erzeugten Lichtsäulen. p. 150–152.

Schmidt, Wilhelm. Über die virtuelle Temperatur des Himmels. p. 152–153.

Friedmann, A. Zur Theorie der Vertikaltemperaturverteilung. p. 154–156.

Kassner, C[arl]. Windrosenpapier. p. 157–158.

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Hillers, Wilhelm. Nachtrag zu einer Bemerkung über die Abhängigkeit der dreifachen Luftspiegelung nach Vince von der Temperaturverteilung. p. 303–304.

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Arendt, Th[eodor]. Nachruf auf Georg Lachmann. Anhang p. 1–8.

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Henze, H[ermann]. Über Temperaturänderungen in den Sommermonaten sonnenfleckenarmer Jahre zu Berlin. Anhang p. 19–22.

Arendt, Th[eodor]. Gewitterböen. Anhang p. 22–33.

Brämer, K[arl]. Blitzschäden bei den Mai- und Junigewittern in Deutschland 1909–1910. Anhang p. 34–46.

Hellmann, G[ustav]. Zur Bestimmung der Lufttemperatur. Anhang p. 46–51.

Barkow, E[rich]. Bericht über die Vergleichung der Hauptbarometer Berlin-Potsdam und Buenos Aires. Anhang p. 51–53.

König, W[illi]. Die Gewittertätigkeit in Norddeutschland am 3. Juni 1913. Anhang p. 66–77.

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Süring, R[einhard]. Über die Bestimmung der relativen Wolkengeschwindigkeit. Anhang p. 87–95.

Lachmann, G[eorg]. Linien gleicher Luftdichte (Isopyknen). Anhang p. 96.

Brückmann, W[alter]. Zur Frage der Glaskugel-Sonnenscheinautographen. Anhang p. 102–107.

Knoch, K[arl]. Über die Kompensation des Temperatureinflusses bei Aneroidbarographen. Anhang p. 116–133.

Wetter. Berlin. 31. Jahrgang. März 1914.
Arendt, Th[eodor]. Über Niederschlagsveränderlichkeit. p. 49–54.
Thraen, August. Wie wird der Mai 1914? p. 54–63.
Meissner, Otto. Der tägliche Gang der Windstärke in Borkum und Hamburg (1901–1910). p. 63–65.
Preusse, H. Der wetterkundliche Unterricht in einklassigen Volksschulen, p. 69–72.

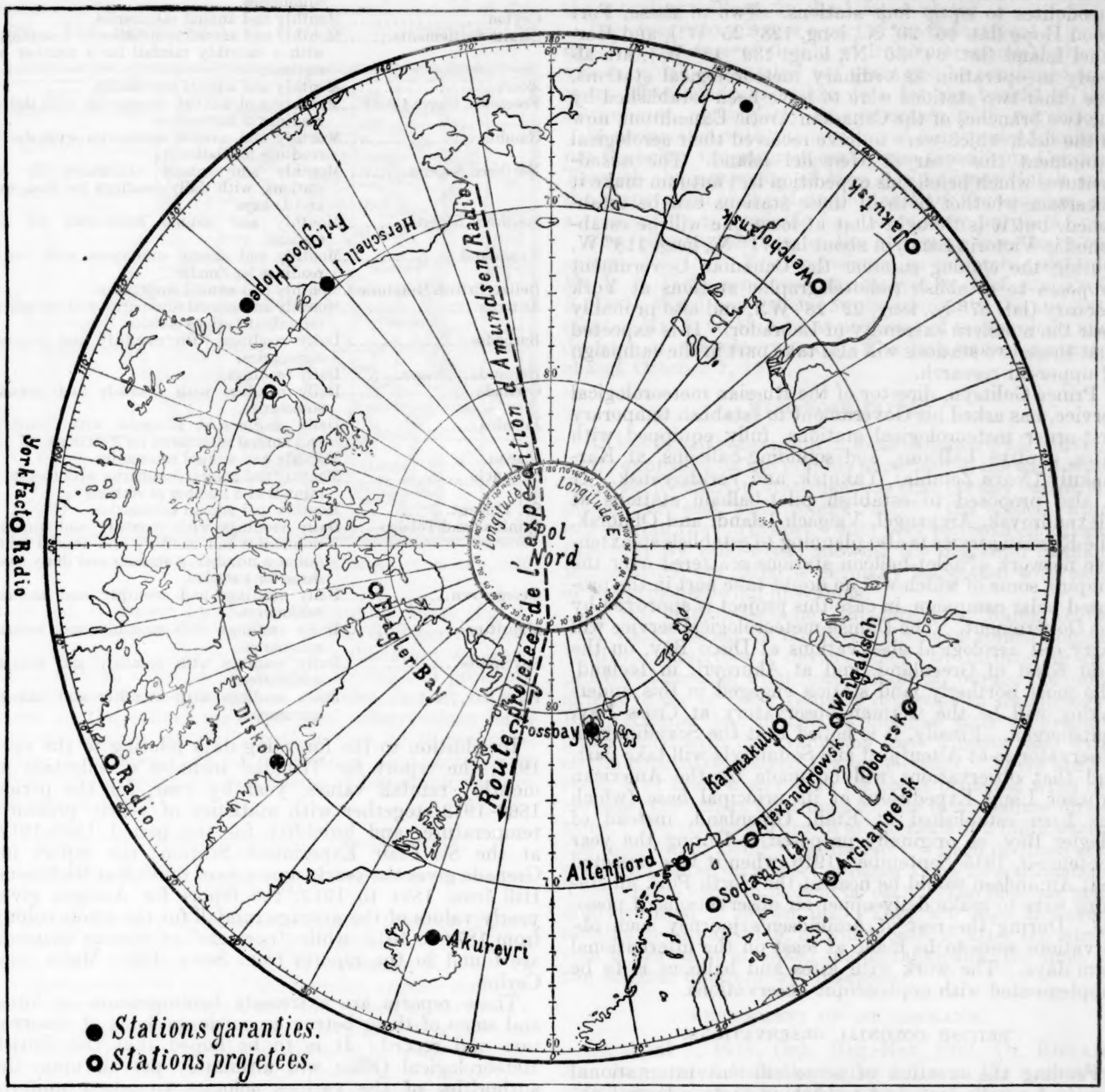

FIG. 1.—Proposed route of Capt. Amundsen's arctic expedition, and location of stations that are to collaborate in aerological observations. (From Bulletin Imp. Acad. Sci., St. Petersburg, April 1, 1914. For English spelling of names see text.)

NOTES FROM THE WEATHER BUREAU LIBRARY.

By C. FITZHUGH TALMAN, Junior Professor, in charge of Library.

INTERNATIONAL AEROLOGICAL OBSERVATIONS IN THE ARCTIC.

The Bulletin of the Imperial Academy of Sciences of St. Petersburg, of April 1, contains an account of a meeting in Copenhagen, February 28–March 1, 1914, of the commission recently appointed by the International Meteorological Committee to carry out a series of aerological observations at a chain of stations extending around the north polar basin (see fig. 1), simultaneously with the similar observations which are to be made by Capt. Amundsen, during his coming north polar drift. The membership of this commission is as follows: Gen. Rykachev (president), R. Amundsen, H. Hergesell, C. Ryder, R. F. Stupart, B. Birkeland, Prince Golitsyn, A. de Quervain, and A. Wegener (secretary).

The plans formulated at this meeting were based on the assumption that Capt. Amundsen would set out on his expedition next summer, and undoubtedly some modifications will be necessitated by the fact that the expedi-

tion has now been postponed until the summer of 1915 (There is, in fact, a possibility that it may be abandoned altogether, on account of insufficient funds.)

The arrangements so far made are as follows: The chief physicist of the meteorological service of Canada expected to make a trip down the Mackenzie River, in April, 1914, to the Arctic Ocean, taking with him enough balloons and theodolites to equip four stations. Two of these, Fort Good Hope (lat. 66° 20′ N., long. 128° 25′ W.), and Herschel Island (lat. 69° 30′ N., long. 139° 15′ W.), are already in operation as ordinary meteorological stations. The other two stations were to have been established by the two branches of the Canadian Arctic Expedition, now in the field, which were to have received their aerological equipment this year at Herschel Island. The misadventures which befell this expedition last autumn make it uncertain whether both of these stations can be established, but it is thought that at least one will be established in Victoria Land, in about lat. 71° N., long. 118° W. During the coming summer the Canadian Government proposes to establish radiotelegraphic stations at York Factory (lat. 57° N., long. 92° 28′ W.), and also probably near the northern extremity of Labrador. It is expected that these two stations will also take part in the campaign of upper-air research.

Prince Golitsyn, director of the Russian meteorological service, has asked his Government to establish temporary first-order meteorological stations, fully equipped with kites, captive balloons, and sounding-balloons, at Karmakuly (Nova Zembla), Yakutsk, and Verkhoyansk. It is also proposed to establish pilot-balloon stations at Alexandrovsk, Archangel, Vaigach Island, and Obdorsk. The Russian service is also planning to establish an extensive network of pilot-balloon stations scattered over the Empire, some of which will no doubt take part in the proposed polar campaign, in case this project is approved by the Government. The Danish meteorological service will carry out aerological observations at Disco Bay, on the west coast of Greenland, and at Akureyri, in Iceland. The most northerly land station engaged in this undertaking will be the German observatory at Cross Bay, Spitsbergen. Finally, it is hoped that the Scandinavian observatories at Altenfjord and Sodankyla will take part, and that observations will be made by the American Crocker Land Expedition, at its principal base (which has been established at Etah, Greenland, instead of Flagler Bay, as originally proposed). During the year September, 1915–September, 1916, when it was expected that Amundsen would be nearest the North Pole, all stations were to make daily upper-air observations, if possible. During the rest of Amundsen's journey such observations were to be made at least on the international term days. The work with kites and balloons is to be supplemented with nephoscopic observations.

BRITISH COLONIAL OBSERVATIONS.

Pending the creation of some efficient international service for collecting and publishing meteorological observations from portions of the world lying outside of the great national *réseaux*, the British Meteorological Office is entitled to our gratitude for the system which it inaugurated a few years ago of assembling from the "blue books" of the various British colonies extracts of those portions containing meteorological observations, and distributing these promptly to the principal meteorological libraries of the world. Before this plan was adopted, meteorological data were almost unobtainable from some of the smaller colonies in question. The collection of observations for the year 1912, just distributed, includes the following data:

Gibraltar	Monthly and annual summaries.
Cyprus	Monthly and annual summaries for 6 stations.
Malta	Monthly and annual summaries for 7 stations.
Hongkong	Daily readings and monthly and annual summaries.
Ceylon	Monthly and annual summaries.
Straits Settlements	Monthly and annual summaries for 5 stations, with a monthly rainfall for a number of stations.
Accra	Monthly and annual summaries.
Freetown, Sierra Leone	Monthly and annual summaries with daily readings of barometer.
Gambia	Monthly and annual summaries with daily readings for Bathurst.
Northern Nigeria	Monthly and annual summaries for 19 stations, with daily readings for Zungeru and Lokoja.
Southern Nigeria	Monthly and annual summaries for 33 stations.
Nyasaland	Monthly and annual summaries. with daily readings for Zomba.
Belize(British Honduras)	Monthly and annual summaries.
Antigua	Monthly and annual summaries with monthly rainfall at various stations.
Barbados	Daily readings with monthly and annual summaries.
Bermuda	Daily readings.
Grenada	Daily readings with monthly and annual summaries.
Jamaica	Daily readings at Kingston with monthly and annual summaries for 2 stations.
Nassau	Monthly and annual summaries.
St. Lucia	Monthly and annual summaries with monthly rainfall at a number of stations.
St. Vincent	Monthly and annual summaries.
Trinidad and Tobago	Daily readings with monthly and annual summaries and monthly and annual rainfall at a number of stations and daily sunshine for 1 station.
Georgetown	Daily readings and monthly and annual summaries.
Mauritius	Daily readings with monthly and annual summaries.
Seychelles	Daily readings with monthly and annual summaries.
Fiji	Daily readings with monthly and annual summaries.

In addition to the foregoing data relating to the year 1912, the report for Trinidad includes a collection of monthly rainfall values, year by year, for the period 1862–1912, together with statistics of yearly pressure, temperature, and humidity for the period 1888–1912, at the St. Clair Experiment Station; the report for Grenada gives the yearly amounts of rainfall at Richmond Hill from 1891 to 1912; the report for Antigua gives yearly values of the average rainfall for the whole colony from 1874 to 1912; while "normals" of various elements are found in the reports from Suva (Fiji), Malta, and Ceylon.

These reports are extremely heterogeneous in form, and some of them betray eccentric methods of observation and record. It is to be hoped that the British Meteorological Office will ultimately prevail upon the authorities of the various colonies to adopt uniform term-hours, registers, instrumental equipment, etc., conforming as far as possible to the recommendations of the International Meteorological Committee.

METEOROLOGY IN THE BELGIAN KONGO.

During the past decade climatographic investigations have made more striking progress in Africa than in any other continent. The necessity of collecting climatic statistics, as a preliminary to the agricultural exploitation

of a virgin country, is now fully realized by the officials administering most of the European colonies in Africa; this is true especially of the German and British colonies, all of which are well supplied with meteorological stations.

In the Belgian Kongo a well-organized climatological service dates only from the year 1911. This service, which is under the Direction de l'Agriculture, includes 4 stations of the first order, 2 of the second, and 34 of the third. The distribution of stations, in operation or

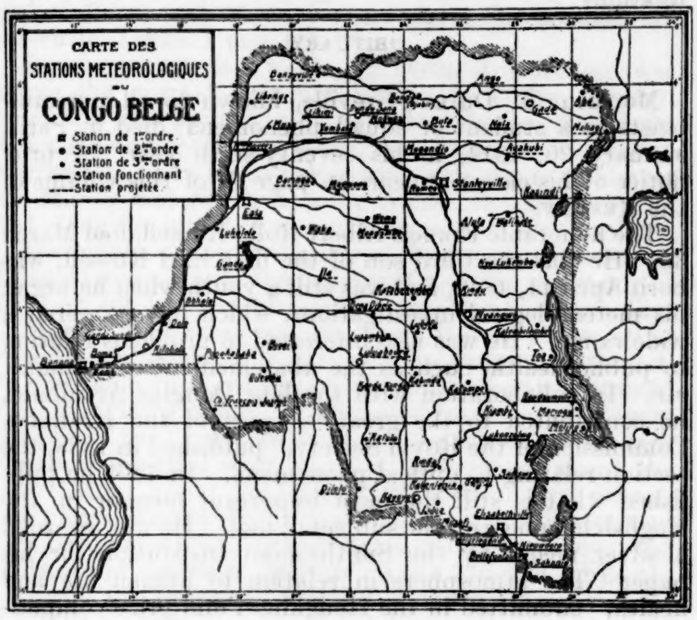

FIG. 2.—Map of meteorological stations in the Belgian Kongo. (From Agric. Bull. of Belgian Kongo.)

projected, is shown by the accompanying chart (fig. 2) from the March, 1913, number of the Bulletin Agricole du Congo Belge. From the same publication we learn that a rainfall chart of the Belgian Kongo will probably be published in four or five years; also that at several places in the colony meteorological observations have been undertaken especially with a view to the requirements of aviation. It is understood that aeroplanes will be extensively used as a means of communication in this part of Africa.

BLUE HILL METEOROLOGICAL OBSERVATORY.

[Extracted from Report Harvard College Astronomical Observatory for the year ending Sept. 30, 1913.]

Pending the formal transfer in March, 1913, of the observatory to Harvard University, all costs of maintenance were defrayed by Mrs. A. Lawrence Rotch. In accordance with the wish of the founder, regular observations have been continued and the record now covers a period of 28 consecutive years. Normals for a 25-year period have been prepared and will soon be ready for publication. The usual work of the observatory was carried on without interruption. Comparative readings at the auxiliary stations, known as the base and valley stations, are now available for a period of nearly 25 years. These data will be utilized in studies of best methods of protecting vegetation from injury by frost.

Upper-air investigation by means of kites was continued until March, the last flight occurring March 7. This was during a thunderstorm and a discharge of lightning melted a mile of wire and damaged the kite reel. Two of the observers were shocked, one severely, but fortunately no permanent injury resulted. For various reasons the use of ballon-sondes or sounding balloons is preferable in exploring the upper air and the kite method is being generally abandoned. Continuance of the kite work is problematical. Blue Hill Observatory[1] was one of the first—if not, indeed, the first—observatories, to fly kites for aerological research. It was also the first to use the sounding balloon, in the United States.

The observatory is now a part of the department of geology, but the close affiliation with the astronomical observatory which has existed for years will be continued and every effort made to utilize data for the benefit of the astronomer, particularly in connection with refraction.

In connection with the erection of a memorial fountain not far below the summit, water was piped from Canton. Through the generosity of Mrs. A. Lawrence Rotch and the cooperation of the Metropolitan Park Commission, an ample supply is available for observatory purposes.

The following changes in the observing force have occurred: Mr. C. F. Brooks resigned as research assistant; Mr. L. A. Wells continued as observer in chief, and Prof. R. De C. Ward had general supervision until the appointment of Mr. A. G. McAdie as professor of meteorology and director of the observatory. The last named assumed charge October 1, 1913.

WIND-ROSE PAPER.

An important conception in local climatology is conveniently expressed by the graphic expedient of the wind-rose. Thus, such indefinite statements as that (at any particular place) "an east wind brings rain," "the coldest wind comes from the northwest," etc., may be replaced advantageously by wind-roses, showing the degree of rainfall, temperature, etc., that is normally associated with each of the principal wind directions.

In the Meteorologische Zeitschrift for March, 1914, Prof. Carl Kassner, of the Royal Prussian Meteorological Institute, describes a device which, by facilitating the process of drawing wind-roses, should encourage the more extensive use of these valuable diagrams in climatology. Prof. Kassner has induced a German firm to prepare paper ruled with lines radiating from a center and with circles concentric around the same center. There are 16 radii; 8 of them heavy lines for the 8 principal wind directions, the others light lines for the intermediate directions. The circles are drawn at intervals of 2 millimeters, the total radius being 8 centimeters. Each of these diagrams is printed on a sheet of paper 22 by 28 centimeters. These sheets come in pads of 50 each. The lines are generally printed in brown ink. They are also, however, obtainable in pale blue; in which case, if, after the wind-rose is drawn, it is copied photographically, the lines of the original diagram will disappear.

RETIREMENT OF DR. ASSMANN.

On April 1, 1914, Geh. Reg.-Rat. Prof. Dr. Richard Assmann retired from the active duties in the execution of which he has been, for a number of years, perhaps the most conspicuous figure in German meteorology. An appreciative sketch of his career is published in the Deutsche Luftfahrer Zeitschrift by the editor, Herr Paul Béjeuhr.

Assmann was born in Magdeburg in 1845, and began his public career as a doctor of medicine. He soon, however, turned his attention to meteorology, and from 1881

[1] The history of the use of kites in aerological research was set forth in the REVIEW for January, 1914, p. 39.—EDITOR.

to 1885 served as director of the weather observatory of the Magdeburgische Zeitschrift. He left this post to become a privatdocent at Halle, and was called from there to Berlin to become a member of the staff of the Royal Prussian Meteorological Institute. One of his most notable achievements at this period was the invention of the aspiration psychrometer.

At Berlin, Assmann soon identified himself with the development of scientific aeronautics, and this has ever since remained his most congenial field of activity. He succeeded in arousing great enthusiasm in behalf of scientific balloon ascents, and instituted the series of such ascents of which the results are recorded in the monumental work, "Wissenschaftliche Luftfahrten," published in three volumes in 1899–1900. Of this work, which may be regarded as a corner stone of the new science of aerology, Assmann was the principal editor. In 1899 he took a lead in the establishment of the first observatory ever created solely for upper-air investigations. Of this institution at first situated at Tegel, but moved in 1904 to Lindenberg, Assmann has been director almost from the beginning, and under his charge it has become an all-important center of aerological investigations, both theoretical and practical. An example of its direct utility to the aeronaut is found in the unique work of the aeronautical storm-warning service, of which the Lindenberg Observatory is the headquarters. When one considers Assmann's indefatigable industry in developing upper-air research, together with the fact that he was one of the discoverers of the isothermal layer, the title "father of aerology," conferred on him by Herr Béjeuhr, hardly seems an excessive compliment.

Assmann's scientific industry has been truly remarkable. He has edited the meteorological journal, "Das Wetter," since its foundation in 1884; has been joint editor with Hergesell of "Beiträge zur Physik der freien Atmosphäre" since its foundation in 1904; and has edited the, to meteorologists, indispensable "Kosmische Physik" volume of "Fortschritte der Physik" since 1887, in addition to the annual report of the Lindenberg Observatory, which is itself a scientific journal of great importance.

We may assume that freedom from administrative duties will enable Dr. Assmann to prosecute even more vigorously than in the past his admirable scientific investigations.

OBITUARY.

Monsieur E. Durand-Gréville, known to all meteorologists as a student of squall phenomena, died in Paris, January 20, 1914, in his seventy-sixth year. A brief notice of his career appears on page 97 of this volume of the REVIEW.

The honorable Francis Albert Rollo Russell died March 30. He was the third son of the first Earl Russell, was born April 11, 1849, and was still a youth when he began his meteorological investigations, which have covered a wide range. He was also interested in problems relating to public health, such as the abatement of coal smoke, etc. In collaboration with the late Douglas Archibald, he contributed to the great "Report of the Krakatoa Commission of the Royal Society," published in 1888, the section relating to optical phenomena. In 1891 he published what is still the most important memoir in the English language on the subject of hail. He was awarded a silver medal by the Smithsonian Institution for his paper "The atmosphere in relation to human life and health," submitted in the Hodgkins Fund prize competition. He was a vice president of the Royal Meteorological Society in 1893–94.

SECTION VI.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH.

By P. C. DAY, Climatologist and Chief of Division.

Pressure.—The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds, are graphically shown on Chart VII, while the averages for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

For the month as a whole the barometric pressure was above the normal over practically the entire country, especially over the west Gulf and Plains States, the Rocky Mountain and northern Plateau regions, and the Canadian Northwest. The mean values were near the normal over the Middle and North Atlantic States, the Lake region, and along the middle and southern coast of California.

The month opened with extremely low pressure on the Atlantic coast, due to the passage of a severe storm northward on the last day of February and the first two days of March, the lowest reading, 28.25 inches, occurring at New Haven, Conn., at 7 a. m., on the morning of the 1st. At the same time comparatively high pressure obtained over the Plains region. Barometer readings were again low east of the Rocky Mountains on the 4th–7th, while high pressure prevailed over most of the country about the 11th–15th. About the 16th to 19th a barometric depression passed eastward over the northern tier of States, and high barometer readings were again quite general over the central and southern districts on the 22d–23d, while abnormally low pressure prevailed to the northward about the 24th to 26th.

The distribution of the highs and lows for the month was such as to favor the occurrence of westerly or northerly winds as prevailing directions in the Atlantic Coast States, the Lake region, and the upper Mississippi and Missouri Valleys, while winds from a southerly direction were the rule in the west Gulf States. Over the western districts the winds, as a rule, were variable.

Temperature.—The first decade of the month was warm from the upper Lake region westward to the Pacific and generally over the Southwest, the excess in temperature being most marked in the upper Missouri Valley and along the Pacific coast, where it ranged from 10° to 15° per day. Over the lower Lake region and Ohio Valley and from the lower Mississippi Valley eastward to the Atlantic coast the weather was cold throughout the period, especially so near the first of the month.

During most of the second decade the temperature continued high in the western districts, notably on the Pacific coast and over the Missouri Valley and Rocky Mountain regions, where the excess ranged from 10° to nearly 20°. There was a general warming up over the districts where cold weather had prevailed during the first decade, except near the Gulf and South Atlantic coasts, where it continued moderately cool.

The early part of the last decade was cold over much of the country, but especially so in the southeastern portions, where frosts were frequent, except over the Florida peninsula. Generally cold weather prevailed over the northern districts during this period and continued to the end of the month, but in the Ohio Valley and to the southward, as well as in the Atlantic Coast States as far north as Virginia the last week of the month was warm and springlike. On the Pacific coast warm weather continued, but the excesses in temperature above the normal were not so pronounced as during the preceding decades.

For the month as a whole the mean temperature was above the normal from the Lake region and middle Mississippi Valley westward to the Pacific as well as over most of New England. From the Ohio Valley and Middle Atlantic States southward to the Gulf and over much of Texas the average temperature was well below the normal.

Extremes of temperature were not marked over any of the interior and northern portions of the country, but high temperatures prevailed on the Pacific coast from the 17th to 19th, the readings at points in California exceeding by several degrees any previous high records for March. Likewise over the southeastern districts the minimum temperatures of the 2d were the lowest ever recorded in March at points in Virginia, the Carolinas and Georgia, and they were again quite low in these districts about the 9th and the 21st.

East of the Rocky Mountains minimum temperatures of 32° occurred nearly to the Gulf coast and they were near zero in the southern portion of the Appalachian Mountain region. On the Pacific coast temperatures did not reach the freezing point, and they were not below 40° at any time during the month over the lower elevations of California.

Precipitation.—The geographic distribution of the precipitation during the month is illustrated on Chart V, the notable features of which are the heavy falls in the lower Mississippi Valley, especially in western Mississippi and Louisiana, and the light amounts or entire absence over the greater portion of the Plateau region.

The precipitation for the month was above the normal in the lower Mississippi Valley and eastern Texas. Likewise in New England and New York and over smaller areas in the lower Missouri Valley and the Dakotas. With these exceptions the precipitation was quite generally below the normal in practically all districts, being especially light over much of the Plateau region, notably in Nevada, much of Utah, southern Idaho, and portions of Washington and Oregon. The amounts east of the Rocky Mountains, while mostly below the normal, were well distributed and sufficient for agricultural requirements.

Snowfall and ice.—Heavy snow occurred at the first of the month in portions of New York, eastern Pennsylvania, and adjacent States, and unusually heavy amounts fell near the end of the second decade in the Middle Atlantic States, especially in Virginia and North Carolina, but otherwise little occurred in any portion of the country. The amounts in the western mountain regions were unusually light and the ground at the lower elevations was bare throughout the month. Much of the snow at moderate elevations disappeared, and the outlook is for a somewhat reduced supply of water for irrigation, except in California and portions of middle Plateau and Rocky Mountain regions.

The heavy covering of snow over the upper Ohio drainage and the North Atlantic States remained largely unmelted until near the end of the month, when high temperatures and warm rains caused rapid melting, with attendant floods in many of the smaller streams of that region. The snow had practically disappeared from the upper Lake region by the end of the month, and the generally light fall during the winter and its early melting interfered seriously with lumbering operations in that district.

The continued moderately cool weather and absence of heavy rains favored the slow breaking up of the ice on the rivers and its passing out without material obstruction, except in the smaller streams in the Northeastern

States. The harbors of the upper Lake region remained closed, but those of the lower Lakes were mostly free of ice at the end of the month.

General summary.—Over the east-central and southeastern portions of the country the month as a whole was cold and unfavorable for outdoor occupations. Some severe frosts occurred in the east Gulf and South Atlantic States, but the generally cold weather during the preceding month had delayed the development of vegetation and no serious damage was reported, except in small portions of Florida.

In the middle-western districts the weather was more favorable and much outdoor work was possible. Decided changes in temperature were infrequent, and wheat and grass appear to have come through the winter in excellent condition.

In the districts from the Rocky Mountains westward the month was favorable throughout, except that little precipitation occurred and the outlook for irrigation water was not improved. Vegetation advanced rapidly in the southern portions and was in good condition at the end of the month.

Average accumulated departures for March, 1914.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	Inches	Inches	Inches			P. ct.	P. ct.
New England	33.1	+0.2	− 5.8	3.51	0.00	−1.00	6.4	+0.7	77	+ 2
Middle Atlantic	37.1	−2.8	− 4.3	3.13	−0.50	−0.60	6.1	+0.4	72	0
South Atlantic	49.5	−4.4	− 3.3	2.37	−1.90	−2.30	4.6	−0.3	69	− 6
Florida Peninsula	65.4	−4.3	− 5.4	0.90	−1.40	−1.20	4.4	−0.6	74	− 3
East Gulf	53.0	−4.3	− 4.0	4.00	−1.80	−0.40	4.8	−0.2	68	− 5
West Gulf	55.0	−2.8	+ 1.1	3.51	+0.40	−2.20	5.0	−0.1	67	− 5
Ohio Valley and Tennessee	40.9	−3.2	− 3.4	2.78	−1.60	−3.10	6.4	+0.4	73	+ 2
Lower Lakes	31.8	−1.1	− 5.3	3.05	+0.40	−0.40	6.5	−0.1	78	+ 2
Upper Lakes	28.0	+0.5	− 0.8	1.58	−0.70	−1.00	6.3	+0.3	77	− 2
North Dakota	26.2	+5.2	+ 9.5	0.99	0.00	−0.20	6.2	+0.6	78	0
Upper Mississippi Valley	36.8	+0.8	+ 4.5	1.59	−0.80	−1.40	6.0	+0.3	75	+ 2
Missouri Valley	38.1	+2.0	+ 9.1	1.86	−0.10	−0.30	5.4	−0.3	69	− 3
Northern slope	35.0	+4.2	+11.9	0.68	−0.50	−0.70	5.5	+0.1	64	− 3
Middle slope	43.8	+1.3	+10.4	1.05	−0.40	−1.00	4.4	−0.2	59	− 1
Southern slope	53.0	−0.2	+ 8.2	0.39	−0.60	−2.30	3.8	−0.6	50	− 5
Southern Plateau	52.4	+1.4	+ 4.6	0.51	0.00	−0.50	2.4	−1.3	47	+11
Middle Plateau	43.7	+3.4	+ 9.2	0.37	−0.90	+0.20	2.9	−2.1	50	− 6
Northern Plateau	44.9	+4.6	+13.8	0.56	−1.00	−0.70	5.8	0.0	58	− 8
North Pacific	47.8	+3.6	+ 9.9	2.66	−2.30	+1.50	6.9	+0.3	81	+ 6
Middle Pacific	55.7	+4.4	+ 7.4	1.28	−2.90	+0.50	3.9	−1.5	69	+ 5
South Pacific	60.6	+5.3	+11.8	0.61	−2.00	+4.60	3.5	−2.3	66	− 5

Maximum wind velocities, March, 1914.

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
		Mi/hr.				Mi/hr.	
Atlanta, Ga	1	52	nw.	New York, N. Y	18	52	w.
Block Island, R. I	1	84	e.	Do	19	61	nw.
Boston, Mass	1	50	e.	Norfolk, Va	1	55	w.
Buffalo, N. Y	2	50	nw.	Do	2	60	w.
Chattanooga, Tenn	17	51	nw.	North Head, Wash	1	50	s.
Cheyenne, Wyo	4	54	w.	Do	3	52	se.
Do	15	62	w.	Do	28	54	se.
Do	24	58	w.	Do	29	62	se.
Do	25	50	sw.	Do	30	56	se.
Cleveland, Ohio	2	50	nw.	Oklahoma, Okla	10	52	n.
Eastport, Me	1	52	ne.	Do	19	50	n.
Do	2	60	ne.	Do	28	54	s.
Do	6	56	ne.	Point Reyes Light, Cal	1	59	nw.
Do	7	54	ne.	Do	2	55	nw.
Hatteras, N. C	1	54	nw.	Do	28	68	s.
Do	2	58	nw.	Do	29	67	s.
Lander, Wyo	27	56	sw.	Port Huron, Mich	1	50	nw.
Lynchburg, Va	1	50	nw.	Portland, Me	1	55	e.
Do	2	55	nw.	Providence, R. I	1	58	se.
Modena, Utah	23	51	s.	Do	19	50	nw.
Mt. Tamalpais, Cal	1	62	nw.	Sand Key, Fla	1	54	nw.
Mt. Weather, Va	1	110	nw.	Sandusky, Ohio	1	56	nw.
Do	2	108	nw.	Savannah, Ga	1	62	nw.
Do	3	72	nw.	Tatoosh Island, Wash	1	65	sw.
Do	4	50	nw.	Do	3	50	s.
Do	18	62	nw.	Do	9	54	s.
Do	19	74	nw.	Do	13	56	s.
Do	20	58	nw.	Do	30	52	s.
Nantucket, Mass	1	86	se.	Toledo, Ohio	25	55	sw.
Do	6	57	ne.	Trenton, N. J	1	58	nw.
Nashville, Tenn	1	52	nw.	Washington, D. C	1	56	nw.
New Haven, Conn	1	58	ne.	Do	2	60	nw.
New York, N. Y	1	84	nw.				
Do	2	72	nw.				

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data, as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Summary of temperature and precipitation, by sections, March, 1914.

Section.	Temperature (°F.).								Precipitation (inches and hundredths).					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
Alabama	51.1	− 6.2	Evergreen	87	30	2 stations	11	2	3.49	− 2.21	Clanton	7.10	Flomaton	1.24
Arizona	54.6	+ 1.9	3 stations	96	16	Chin Lee	9	11	0.68	− 0.31	Natural Bridge	1.76	2 stations	T.
Arkansas	50.0	− 2.6	Camden	86	30	Mammoth Spring	4	20	5.13	+ 0.01	Centerpoint	13.08	Subiaco	2.01
California	55.0	+ 3.2	Pomona	97	17	Bridgeport	− 6	22	1.16	− 3.58	Upper Mattole	7.01	12 stations	0.00
Colorado	34.7	− 0.1	Lamar	83	15	Fraser	−34	21	0.80	− 0.58	Silver Lake	3.87	2 stations	0.00
Florida	60.1	− 6.0	Eustis	91	28†	De Land	26	9	1.51	− 1.61	Pensacola	3.64	Live Oak	0.17
Georgia	51.7	− 5.4	3 stations	89	29†	Lost Mountain	10	2	2.79	− 2.20	Canton	4.70	Thomasville	1.22
Hawaii (for February)	68.9	......	4 stations	87	2†	Humuula	38	26	2.14	......	Kapoho	7.57	Kahului	T.
Idaho	39.8	+ 3.0	Garnet	75	14†	Pierson	−12	11	0.69	− 1.00	French Gulch	3.54	7 stations	T.
Illinois	38.3	− 1.3	Mascoutah	79	15	Kishwaukee	1	1	2.22	− 0.95	Kishwaukee	4.69	Hillsboro	0.50
Indiana	37.9	− 3.9	Huntingburg	76	26	2 stations	3	12	2.60	− 1.33	Crawfordsville	5.18	Veedersburg	1.27
Iowa	34.7	+ 1.4	Lamoni	78	15	....do	− 5	1	1.69	− 0.08	Clinton	3.84	Lake Park	0.28
Kansas	43.9	+ 1.1	Moran	88	14	Centralia	− 4	20	1.21	− 0.25	Ellsworth	4.42	7 stations	T.
Kentucky	41.8	− 4.5	2 stations	78	15	Beattyville	2	21	3.62	− 1.27	Williamsburg	6.53	Williamstown	2.14
Louisiana	55.8	− 5.8	3 stations	88	28†	2 stations	21	12†	6.63	+ 2.06	Merryville	15.90	Logansport	2 78
Maryland & Delaware	37.9	− 4.5	Western Port	80	26	Deer Park	−14	21	2.48	− 1.22	Deer Park	4.55	College Park	1.15
Michigan	28.0	− 0.8	Bay City	69	30	Humboldt	−27	20	1.53	− 0.57	Wasepi	3.62	Harbor Beach	0.35
Minnesota	26.6	+ 1.6	Farmington	68	15	Roseau	−30	1	1.12	− 0.10	Campbell	2.84	2 stations	0.30
Mississippi	52.3	− 5.8	Jackson	88	30	Booneville	17	2	6.27	+ 0.78	Vicksburg	12.29	Crenshaw	2.68
Missouri	43.2	− 1.3	Joplin	87	15	Louisiana	− 2	4	2.75	− 0.41	Macon	5.80	Hermann	0.91
Montana	34.0	+ 4.7	Chinook	72	31	Bowen	−21	11	0.67	− 0.28	Garneill	3.58	Malta	0.02
Nebraska	36.7	+ 1.5	Falls City	81	15	2 stations	−11	20	1.10	− 0.02	Falls City	4.12	Haigler	T.
Nevada	44.4	+ 3.5	Logan	87	15	Tecoma	4	23	0.19	− 0.90	Hylton	1.15	15 stations	0.00
New England	32.0	+ 0.8	Boston, Mass	74	27	Hyde Park, Vt	−15	12	4.11	+ 0.23	Norwalk, Conn	6.64	Houlton, Me	1.20
New Jersey	35.4	− 2.6	5 stations	75	27	Vineland	− 6	21	3.65	− 0.37	Charlotteburg	6.45	Vineland	2.02
New Mexico	43.2	− 1.2	Deming	90	17	Elizabethtown	−10	22	0.40	− 0.30	Harveys Up. Ranch	2.92	5 stations	0.00
New York	29.6	− 2.0	Port Jervis	72	27	Ranger School	−30	12	3.51	+ 0.31	Mohonk Lake	8.95	Ogdensburg	1.35
North Carolina	44.8	− 5.8	3 stations	85	30	Banners Elk	2	2	3.10	− 1.54	Banners Elk	5.87	Charlotte	1.56
North Dakota	25.4	+ 3.1	2 stations	76	13†	3 stations	−20	10†	0.87	0.00	Turtle Lake	1.82	Park River	0.24
Ohio	36.0	− 3.4	Syracuse	78	26	Peebles	− 2	12	2.42	− 1.04	Upper Sandusky	3.67	Bellpoint	1.45
Oklahoma	50.2	− 2.2	Weatherford	90	28	3 stations	8	20	2.02	− 0.16	Idabel	7.64	Hurley	T.
Oregon	46.5	+ 4.1	Brookings, No. 3	88	9†	Cliff	4	26	2.16	− 1.19	Happy Home	12.57	Redmond, No. 2	0.00
Pennsylvania	34.2	− 3.9	Hamburg	79	27	Lawrenceville	−12	12	2.61	− 1.14	Scranton	5.05	Hamburg	0.88
Porto Rico	74.2	+ 0.5	2 stations	94	15†	Maricao	50	14†	5.61	+ 1.74	Arecibo	12.35	Josefa	0.60
South Carolina	50.2	− 4.7	Blackville	91	30	Spartanburg	12	2	2.59	− 1.37	Summerville	4.05	Calhoun Falls	0.80
South Dakota	31.6	+ 1.5	Greenwood	78	13	Sorum	−12	26	0.72	− 0.47	Dumont	2.98	Oelrichs	T.
Tennessee	44.9	− 5.5	Pinewood	80	30	Tazewell	3	21	4.50	− 0.80	Rugby	7.16	Dover	2.72
Texas	56.3	− 2.9	Fort McIntosh	95	28†	Plemons	8	20	2.45	+ 0.35	Hempstead	11.05	4 stations	0.00
Utah	41.0	+ 1.8	Cisco	90	14	2 stations	− 3	3	0.63	− 0.85	Maple Creek	2.19	Cisco	0.00
Virginia	40.6	− 4.6	Charlottesville	79	17	Burkes Garden	−15	21	3.16	− 0.70	Speers Ferry	6.74	Mount Weather	1.66
Washington	44.5	+ 3.4	Mottinger	87	10	Antoine	− 2	26	2.17	− 1.06	Quiniault	10.06	3 stations	0.00
West Virginia	37.3	− 6.5	Spencer	83	26	Bayard	−13	12	3.03	− 1.22	Pickens	7.11	Moundsville	0.89
Wisconsin	28.1	− 0.7	Muscoda, No. 2	69	15	Long Lake	−23	2	1.49	− 0.23	Delavan	3.59	Ashland	0.26
Wyoming	30.8	+ 2.0	Wheatland	80	25	Foxpark	−34	21	0.64	− 0.69	Dome Lake	3.36	2 stations	0.00

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m., seventy-fifth meridian time daily, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.8

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred, the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, and depth of snowfall, and the respective departures from normal values, except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., seventy-fifth meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading and (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea level and standard gravity.

Chart IV.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading, and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart V.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VI.—Isobars and isotherms at sea level and prevailing wind directions. The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observations, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction $t_0 - t$, or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations; a few stations having no self-recording wind direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given.

Chart VIII.—Depth of snow on ground at end of the month, expressed in inches and tenths.

Charts VII and VIII are published only when the general snow cover is sufficiently extensive to justify their preparation.

TABLE I.—*Climatological data for United States Weather Bureau stations, March, 1914.*

Districts and stations.	Elevation of instruments.			Pressure in inches.			Temperature of the air, in degrees Fahrenheit.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 or more.	Total movement, miles.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.						
New England.							33.1	+ 0.2										77	3.51	0.0										6.4		
Eastport	76	67	85	29.88	29.97	+0.04	29.6	+ 0.7	49	27	35	8	21	24	19	28	24	80	3.77	− 0.5	16	9,547	w.	60	ne.	2	4	12	15	7.1	18.0	T.
Greenville	1,070	6		28.76	29.96		25.2		55	26	33	− 2	12	18	34				4.15		11										22.6	35.0
Portland, Me.	103	82	117	29.86	29.98	+ .02	32.8	+ 0.8	59	27	39	11	21	27	22	29	24	73	4.37	+ 0.6	14	7,421	nw.	55	e.	1	11	5	15	6.2	8.1	
Concord	288	70	79	29.67	30.00	.00	32.0	+ 0.5	64	26	40	8	21	24	32				3.90	+ 0.5	11	4,941	nw.	46	ne.	1	11	8	12	5.8	8.5	
Burlington	404	11	48	29.54	30.00	.00	29.0	+ 1.7	56	26	36	0	21	22	26				1.84	0.0	12	8,016	s.	45	s.	26	6	7	18	7.2	18.1	T.
Northfield	876	12	60	29.01	29.99	− .01	26.8	+ 0.6	58	26	36	− 5	21	17	37	24	22	86	3.48	+ 0.7	13	5,391	s.	30	s.	16	6	4	21	7.3	28.0	5.8
Boston	125	115	188	29.84	29.98	+ .01	36.7	+ 1.7	74	27	44	16	21	30	29	33	28	74	4.16	+ 0.1	13	8,485	nw.	50	e.	1	8	6	17	6.2	5.2	
Nantucket	12	14	90	29.95	29.96	− .02	35.2	− 1.6	52	16	40	19	21	30	22	33	30	84	4.63	+ 0.6	12	12,962	sw.	86	se.	1	13	6	12	6.0	13.6	
Block Island	26	11	46	29.95	29.98	.00	34.0	− 1.9	50	31	38	16	21	29	16	32	29	83	3.45	− 0.9	11	14,415	sw.	84	e.	1	9	9	13	6.1	10.3	
Narragansett		9					33.7	− 1.3	54	31	40	10	21	27	24				4.36		13		sw.				15	6	10		8.4	
Providence	160	215	251	29.80	29.98	.00	35.6	− 0.1	68	27	42	14	21	29	23	32	27	73	3.38	− 1.2	14	10,526	nw.	58	se.	1	7	13	11	6.1	5.1	
Hartford	159	122	140	29.81	29.99	.00	35.2	+ 0.2	69	27	42	14	21	28	25	31	26	72	4.14	− 0.2	11	6,061	nw.	38	e.	1	6	12	13	6.5	5.9	
New Haven	106	117	155	29.87	29.99	.00	36.1	+ 1.3	68	27	43	15	21	29	27	31	26	71	4.53	+ 0.1	10	7,383	n.	58	ne.	1	7	14	10	5.8	5.0	
Middle Atlantic States.							37.1	− 2.8										72	3.13	− 0.5										6.1		
Albany	97	102	115	29.90	30.01	.00	32.3	+ 0.2	61	27	39	9	13	25	30	29	24	73	3.44	+ 0.7	11	6,134	nw.	35	n.	1	10	12	9	5.6	11.5	
Binghamton	871	10	69	29.05	30.01	− .01	30.6	− 1.4	66	27	38	2	12	23	32				3.89	+ 1.2	11	4,607	nw.	40	nw.	1	2	11	18	7.7	24.0	T.
New York	314	414	454	29.65	30.00	.00	35.8	− 1.7	70	27	43	14	21	29	21	31	25	66	4.55	+ 0.4	9	13,969	nw.	84	nw.	1	5	13	13	6.7	21.5	
Harrisburg	374	94	104	29.65	30.06	+ .04	36.4	− 1.4	72	27	44	12	2	29	28	32	26	68	1.58	− 1.5	10	6,134	nw.	40	nw.	1	4	11	16	6.9	9.1	
Philadelphia	117	123	184	29.91	30.04	+ .02	38.8	− 1.2	72	27	46	16	2	32	30	34	30	74	2.71	− 0.7	12	9,031	nw.	45	nw.	2	5	16	10	6.0	15.2	
Reading	325	81	98	29.68	30.05		36.7		73	27	44	14	2	30	23	32	26	69	1.76		13	6,557	nw.	46	nw.	1	4	13	14	6.6	12.3	
Scranton	805	111	119	29.14	30.03	+ .01	34.1	− 0.8	72	27	41	10	12	27	28	31	27	78	5.05	+ 1.9	10	5,546	n.	44	nw.	1	3	16	12	6.9	20.5	
Atlantic City	52	37	48	29.98	30.04	+ .02	35.0	− 3.8	54	17	41	13	21	29	23	32	28	78	4.10	+ 0.4	12	6,751	nw.	29	ne.	29	8	11	12	6.0	23.6	
Cape May	17	13	49	30.04	30.06	+ .05	36.4	− 4.4	58	17	42	12	21	31	20	33	30	83	4.13	+ 0.4	11	7,623	nw.	42	nw.	1	10	11	10	5.5	20.8	
Trenton	190	159	183	29.80	30.01		35.6		70	27	43	15	2	28	28	32	27	74	3.28	− 0.8	10	9,384	w.	58	nw.	1	9	11	11	5.6	18.8	
Baltimore	123	100	113	29.93	30.06	+ .03	39.6	− 2.3	75	27	47	15	2	32	28	34	28	66	1.80	− 2.1	12	5,962	nw.	35	w.	2	8	15	8	5.6	11.6	
Washington	112	62	85	29.94	30.06	+ .02	29.4	− 2.8	75	27	48	15	21	31	38	34	28	69	2.27	− 1.6	12	7,243	nw.	60	nw.	2	8	10	13	6.1	19.3	
Lynchburg	681	83	88	29.30	30.06	+ .01	42.6	− 2.8	78	16	53	14	2	32	41	36	30	66	2.24	− 1.6	13	7,257	nw.	55	nw.	2	7	18	6	5.5	10.7	
Mount Weather	1,725	10	75	28.15	30.03	− .02	33.3	− 3.5	68	27	40	9	1	26	31	30	26	76	1.66	− 2.3	10	15,904	nw.	110	nw.	1	5	12	14	6.7	11.5	
Norfolk	91	170	205	29.98	30.08	+ .05	42.4	− 5.3	73	27	51	20	2	34	32	37	32	70	3.77	− 0.5	13	11,152	sw.	60	w.	2	11	8	12	5.3	14.0	
Richmond	144	11	52	29.92	30.08	+ .04	41.8	− 5.1	76	16	52	16	21	32	34	36	30	68	3.66	− 0.1	13	7,105	s.	42	nw.	1	11	11	9	5.4	15.8	
Wytheville	2,293	40	47	27.65	30.09	+ .04	37.3	− 5.0	69	28	46	3	21	28	34	33	29	77	3.02	− 1.4	19	5,278	w.	34	w.	18	13	8	10	4.8	10.9	
South Atlantic States.							49.5	− 4.4										69	2.37	− 1.9										4.6		
Asheville	2,255	70	84	27.70	30.12	+ .06	41.0	− 3.9	73	30	51	8	2	31	38	35	30	70	2.34	− 2.7	15	7,416	nw.	42	nw.	2	10	6	15	5.9	5.1	
Charlotte	773	68	76	29.24	30.09	+ .04	46.2	− 4.6	77	28	56	18	2	36	33	39	33	67	1.56	− 3.0	15	6,237	s.	39	w.	7	11	10	10	5.3	6.6	
Hatteras	11	12	50	30.06	30.07	+ .03	46.8	− 4.6	69	27	54	26	2	40	27	43	39	80	2.93	− 2.5	9	11,979	sw.	58	nw.	2	19	1	11	4.1	T.	
Manteo	12	12	46				44.1		71	28	54	23	2	35					2.97	− 2.1	5		ne.				17	4	10		T.	
Raleigh	376	103	110	29.67	30.09	+ .04	45.6	− 4.8	76	28	56	19	2	35	37	38	31	64	3.49	− 0.8	14	7,133	sw.	46	nw.	2	10	14	7	4.9	6.0	
Wilmington	78	81	91	30.02	30.10	+ .05	48.4	− 5.3	76	30	58	22	2	39	28	42	36	70	2.89	− 0.7	8	6,868	w.	42	nw.	1	14	10	7	4.3		
Charleston	48	11	92	30.06	30.11	+ .05	51.2	− 6.0	76	29	60	24	2	43	27	45	40	73	2.34	− 1.4	8	8,583	w.	40	w.	1	18	7	6	3.8		
Columbia, S. C.	351	41	57	29.72	30.11	+ .05	51.2	− 2.8	84	30	62	21	2	40	34	43	35	63	2.08	− 1.6	13	6,214	w.	42	sw.	7	12	12	7	4.7		
Augusta	180	89	97	29.92	30.11	+ .05	52.4	− 3.5	85	30	64	22	2	41	38	44	39	68	1.89	− 3.0	10	5,750	w.	39	nw.	1	13	8	10	5.1	T.	
Savannah	65	150	194	30.05	30.12	+ .06	54.3	− 4.0	83	30	64	24	2	45	28	46	41	70	1.78	− 1.9	6	10,729	w.	62	nw.	1	15	9	7	4.2		
Jacksonville	43	96	129	30.08	30.13	+ .07	57.7	− 4.2	85	29	67	33	2	48	25	49	44	68	1.84	− 1.7	4	7,514	w.	38	w.	1	18	8	5	3.4		
Florida Peninsula.							65.4	− 4.8										74	0.90	− 1.4										4.4		
Key West	22	10	64	30.07	30.09	+ .04	68.8	− 4.0	80	31	74	55	4	64	17	62	59	75	0.50	− 1.0	5	9,372	e.	44	nw.	1	17	6	8	4.2		
Miami	25	37	72	30.08	30.11		65.4	− 6.6	80	28	73	36	3	57	33	60	56	73	0.99	− 1.7	4	6,653	e.	30	nw.	1	11	8	12	5.5		
Sand Key	23	39	72	30.05	30.08	+ .03	68.2		78	20	70	59	3	66	12	63	60	77	0.64		4	12,769	e.	54	nw.	1	15	9	7	4.4		
Tampa	35	79	96	30.09	30.13	+ .06	62.0	− 3.9	85	29	71	40	3	53	29	54	50	73	1.22	− 1.6	3	5,781	ne.	30	nw.	1	18	8	5	3.7		
Titusville	44	6																														
East Gulf States.							53.0	− 4.3										68	4.00	− 1.8										4.8		
Atlanta	1,174	190	216	28.87	30.12	+ .06	48.6	− 3.8	77	29	58	15	2	40	28	42	35	64	3.17	− 2.6	11	9,638	nw.	52	nw.	1	13	4	14	5.3	1.3	
Macon	370	78	87	29.71	30.12	+ .06	52.2	− 2.6	84	30	64	20	2	41	38	45	38	66	1.87	− 3.6	9	5,271	nw.	36	w.	1	13	9	9	4.5	T.	
Thomasville	273	8	57	29.83	30.13	+ .07	55.8	− 4.4	86	31	68	29	9	43	35	47	42	73	1.22	− 3.9	7	4,825	nw.	27	nw.	1	14	13	4	3.9		
Pensacola	56	140	182	30.08	30.14	+ .08	55.2	− 5.9	77	31	62	34	2	48	26	49	44	73	3.64	− 1.7	6	10,437	nw.	44	se	25	15	2	14	5.0		
Anniston	741	9	57	29.34	30.14	+ .08	48.9	− 3.6	79	29	60	17	2	38	36				4.23	− 1.6	12	5,137	nw.	30	nw.	1	13	6	12	5.1	T.	
Birmingham	700	11	48	29.37	30.16	+ .10	50.1	− 5.1	78	29	60	18	2	40	34	42	35	63	5.29	− 0.5	12	6,067	s.	28	nw.	1	13	5	13	5.0	T.	
Mobile	57	125	161	30.08	30.14	+ .08	55.1	− 4.0	77	30	63	34	13	47	29	48	43	70	2.00	− 5.2	9	8,253	nw.	44	nw.	1	14	8	9	4.3		
Montgomery	223	100	112	29.89	30.15	+ .09	53.0	− 4.9	83	30	63	25	2	43	31	46	39	66	2.75	− 3.6	8	5,638	s.	31	nw.	1	14	7	10	4.6		
Meridian	375	85	93	29.73	30.14	+ .09	51.8	− 4.5	85	30	62	28	23	42	35	45	39	67	3.38	− 2.2	11	4,582	nw.	28	nw.	1	10	8	13	5.8	T.	
Vicksburg	247	62	74	29.87	30.15	+ .09	54.5	− 3.7	83	30	64	32	20	45	35	46	39	62	12.29	+ 6.0	8	5,916	s.	26	nw.	7	14	6	11	4.7		
New Orleans	51	90	121	30.08	30.14	+ .10	57.6	− 4.4	84	30	66	39	13	49	28	51	46	71	4.17	− 1.1	9	5,853	se	28	se.	26	13	11	7	4.4		
West Gulf States.							55.0	− 2.8										67	3.51	+ 0.4										5.0		
Shreveport	249	77	93	29.86	30.14	+ .12	55.0	− 3.2	79	29	65	32	8	45	30	48	42	68	6.55	+ 2.0	12	6,561	s.	32	nw.	7	14	7	10	4.7		
Bentonville	1,303	11	44	28.70	30.09	+ .08	46.0	− 1.3	77	14	56	18	20	36	35				3.31	− 0.5	14	2,946	s.	24	s.	24	15	7	9	4.6	4.9	
Fort Smith	457	79	94	29.60	30.09	+ .08	50.6	− 0.7	80	27	60	26	22	41	38	43	35	62	2.45	− 1.2	14	7,070	e.	40	nw.	6	13	3	15	5.5	T.	
Little Rock	357	139	147	29.74	30.12	+ .09	51.0	− 1.7	76	30	60	26	20	42	32	43	36	63	4.63	− 0.3	12	8,191	s.	42	nw.	6	10	14	7	4.9		
Brownsville	57	3	40				63.4		84	28	73	38	20	54	36				1.86		7		s.	36								
Corpus Christi	20	69	77	30.09	30.11	+ .13	60.5	− 3.9	82	5	68	37	20	53	37	55	52	78	1.51	− 0.3	7	9,989	se.	44	se.	10	10	9	12	5.9		
Dallas	512	109	117	29.56	30.12	+ .14	54.5		82	25	65	26	20	44	40				4.09		8	8,499	se.	42	w.	30	12	6	13	4.7		
Fort Worth	670	106	114	29.36	30.08	+ .10	55.5	− 1.1	83	25	66	25	20	44	38	47	40	63	2.89	+ 1.1	7	9,470	s.	38	nw.	19	14	5	12	4.6		
Galveston	54	106	114	30.08	30.14	+ .13	57.2	− 5.1	72	31	62	40	20	52	23	52	49	81	4.63	+ 1.7	8	9,253	s.	37	nw.	19	15	4	12	5.0		
Houston	138	111	121	29.98	30.13		58.8	− 4.7	80	25	68	36	20	50	29				3.94		7	6,953	se.	33	se.	31	12	4	15	5.6		
Palestine	510	64	72	29.57	30.11	+ .11	55.6	− 2.9	80	25	65	30	22	46	34	49	45	74	6.81	+ 3.3	10	6,584	s.	25	n.	19	14	6	11	4.9	T.	
San Antonio	701	80	91	29.37	30.10	+ .12	58.8	− 3.3	81	31	70	34	20	48	42	51	43	65	0.83	− 0.8	5	5,598	se.	36	n.	19	17	6	8	4.0		
Taylor	582	55	63	29.52	30.13	+ .14	56.4	− 3.3	81	25	67	29	22	45	39				1.45	− 1.2	8	8,198	s.	36	nw.	19	11	7	13	5.4	T.	

TABLE I.—*Climatological data for United States Weather Bureau stations, March, 1914*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Pressure in inches. Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air, in degrees Fahrenheit. Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches. Total.	Departure from normal.	Days with 0.01 or more.	Wind. Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
Ohio Valley and Tennessee.							**40.9**	**− 3.2**										**73**	**2.78**	**− 1.6**										**6.4**		
Chattanooga	762	189	213	29.32	30.15	+ .09	47.0	− 4.3	75	16	56	16	2	38	35	41	35	68	3.19	− 3.0	18	6,730	nw.	51	nw.	17	10	7	14	5.8	1.4	....
Knoxville	996	93	100	29.04	30.12	+ .06	44.5	− 3.7	76	28	54	14	2	35	36	39	34	71	3.97	− 1.6	14	4,332	sw.	26	sw.	11	8	6	17	6.3	9.4	....
Memphis	399	76	97	29.72	30.16	+ .12	49.3	− 2.8	75	30	57	22	2	41	34	44	39	70	3.91	− 1.9	10	7,911	sw.	42	nw.	1	12	6	13	5.2	1.0	....
Nashville	546	168	191	29.55	30.15	+ .10	46.0	− 3.2	77	15	54	16	2	38	32	40	34	71	4.33	− 1.1	14	7,718	se.	52	nw.	1	9	7	15	6.1	5.8	....
Lexington	989	75	102	29.01	30.11	+ .06	39.6	− 3.8	71	29	47	12	2	32	28	....	....	....	2.21	− 2.5	13	8,576	s.	44	nw.	1	8	5	18	6.5	5.6	....
Louisville	525	219	255	29.54	30.14	+ .09	42.1	− 3.2	72	29	49	14	2	35	29	37	32	70	3.01	− 1.3	11	9,606	n.	44	nw.	1	9	4	18	6.3	3.7	....
Evansville	431	72	82	29.64	30.12	+ .08	42.0	− 2.6	71	15	49	10	2	35	27	38	33	73	3.12	− 1.5	13	6,113	s.	34	s.	25	9	2	20	6.7	7.4	....
Indianapolis	822	154	164	29.20	30.11	+ .07	37.7	− 1.9	67	15	45	11	1	30	30	34	29	74	1.82	− 2.2	12	7,757	sw.	39	s.	25	8	5	18	7.0	2.0	....
Terre Haute	575	96	129	29.47	30.10	......	39.0	......	69	15	47	9	1	32	31	35	31	78	2.14	......	10	7,586	nw.	37	nw.	1	3	15	13	6.8	2.6	....
Cincinnati	628	152	160	29.42	30.12	+ .07	40.6	− 2.2	71	29	48	14	2	33	32	36	32	76	2.40	− 1.2	13	5,703	w.	28	nw.	1	8	4	19	6.7	4.4	....
Columbus	824	173	222	29.19	30.09	+ .05	36.5	− 2.7	69	26	44	8	2	28	33	33	29	77	2.46	− 0.8	11	7,295	nw.	38	nw.	1	8	7	16	5.9	4.2	....
Dayton	899	181	216	29.10	30.08	......	37.2	− 3.1	66	26	45	10	2	30	29	34	29	76	1.80	− 1.6	10	9,139	nw.	47	sw.	25	11	4	16	6.1	0.7	....
Pittsburgh	842	353	410	29.14	30.07	+ .03	36.8	− 2.7	70	25	44	8	1	30	34	32	27	70	2.12	− 0.9	17	9,865	w.	49	nw.	2	3	8	20	7.7	8.3	....
Elkins	1,940	41	50	27.98	30.11	+ .06	34.0	− 5.1	70	26	45	− 3	21	23	42	30	26	78	2.34	− 1.7	16	3,514	w.	24	w.	18	6	8	17	7.0	20.0	....
Parkersburg	638	77	84	29.44	30.11	+ .06	38.9	− 3.4	75	26	48	9	2	30	35	34	29	72	2.19	− 1.6	18	5,329	sw.	40	nw.	1	8	10	13	6.0	6.0	....
Lower Lake Region.							**31.8**	**− 1.1**										**78**	**3.05**	**+ 0.4**										**6.5**		
Buffalo	767	247	280	29.18	30.03	+ .01	30.1	− 1.1	61	26	37	8	12	23	31	28	25	84	4.18	+ 1.6	15	13,681	w.	50	nw.	2	5	15	11	6.3	22.1	....
Canton	448	10	61	29.51	30.01	......	26.0	− 1.7	55	26	34	− 7	12	18	33	....	....	....	3.03	+ 0.2	16	8,659	w.	37	e.	28	14	6	11	4.9	33.3	T.
Oswego	335	76	91	29.64	30.02	+ .01	29.8	− 1.6	59	26	36	4	12	24	28	28	26	84	3.74	+ 0.9	20	8,286	s.	40	nw.	1	4	8	19	7.4	29.7	....
Rochester	523	86	102	29.45	30.04	+ .02	30.8	− 0.5	65	26	37	6	12	24	30	28	24	77	4.48	+ 1.6	15	7,286	w.	30	nw.	1	5	6	20	7.3	27.9	....
Syracuse	597	97	113	29.36	30.02	.00	30.2	− 1.2	60	26	36	7	12	24	26	28	24	80	4.34	+ 2.0	17	9,420	w.	49	nw.	1	6	6	19	6.9	24.0	....
Erie	714	92	102	29.26	30.05	+ .03	32.4	− 0.7	67	26	39	8	2	26	28	30	25	76	3.00	+ 0.3	16	8,433	w.	35	nw.	2	3	15	13	6.6	13.1	....
Cleveland	762	190	201	29.23	30.07	+ .04	34.0	− 0.2	64	26	41	8	1	27	28	31	26	75	2.10	− 0.7	13	10,826	w.	50	nw.	2	5	13	13	6.4	4.6	....
Sandusky	629	62	70	29.38	30.08	+ .05	33.8	− 1.4	64	26	40	7	2	27	28	30	26	78	2.16	− 0.4	10	10,123	nw.	56	nw.	1	5	10	16	7.0	2.3	....
Toledo	628	208	246	29.38	30.09	+ .06	34.8	0.0	65	26	42	8	2	27	27	30	25	72	2.03	− 0.2	10	11,730	nw.	55	sw.	25	9	6	16	6.2	0.8	....
Fort Wayne	856	113	124	29.14	30.09	......	34.8	− 4.1	62	24	42	11	2	28	32	31	27	77	2.16	......	12	7,977	sw.	42	sw.	25	8	9	14	6.0	4.1	....
Detroit	730	218	258	29.26	30.07	+ .04	33.1	+ 0.2	63	26	40	6	2	26	25	28	24	74	1.44	− 0.9	12	10,321	nw.	48	nw.	1	7	12	12	6.2	2.1	....
Upper Lake Region.							**28.0**	**+ 0.5**										**77**	**1.58**	**− 0.7**										**6.3**		
Alpena	609	13	92	29.39	30.08	+ .05	25.0	0.0	52	25	32	− 1	20	18	25	23	20	81	1.05	− 1.0	15	9,880	nw.	36	nw.	1	5	18	8	6.1	5.7	T.
Escanaba	612	54	60	29.41	30.10	+ .06	24.6	+ 1.1	49	25	32	1	20	18	27	22	18	77	1.50	− 0.4	11	7,836	n.	42	n.	1	6	7	18	6.8	3.1	....
Grand Haven	632	54	92	29.37	30.08	+ .05	31.2	+ 0.4	60	26	38	10	2	24	28	28	24	77	2.05	− 0.5	12	8,932	n.	45	n.	1	8	11	12	5.7	10.0	....
Grand Rapids	707	70	87	29.29	30.09	+ .06	32.0	+ 1.0	65	26	40	9	2	24	27	28	24	76	1.59	− 0.9	8	5,625	nw.	32	nw.	1	8	10	13	6.1	7.5	....
Houghton	684	62	72	29.34	30.10	+ .06	21.8	− 2.0	49	15	30	− 9	20	14	37	....	....	....	0.94	− 1.2	14	6,648	nw.	42	nw.	25	7	13	11	5.9	9.6	1.5
Lansing	878	11	62	29.10	30.07	......	31.1	− 0.2	64	26	40	5	2	22	29	27	23	80	1.52	− 0.7	10	5,956	nw.	28	nw.	1	7	9	15	6.5	2.4	....
Ludington	637	60	66	29.36	30.08	......	29.4	......	56	31	36	8	1	23	24	27	23	78	2.52	......	14	8,262	n.	42	n.	1	6	9	16	6.9	8.1	....
Marquette	734	77	111	29.30	30.13	+ .09	25.0	+ 1.3	50	25	32	2	20	18	24	22	17	75	2.03	0.0	15	8,590	nw.	41	sw.	25	4	8	19	7.4	17.5	1.6
Port Huron	638	70	120	29.34	30.06	+ .03	31.0	+ 1.4	57	26	38	6	20	24	24	27	24	78	1.36	− 1.1	13	9,645	nw.	50	nw.	1	7	11	13	6.1	3.2	....
Saginaw	641	48	82	29.36	30.08	......	30.0	......	62	26	38	2	2	22	30	27	23	81	1.10	− 1.5	10	8,148	nw.	32	s.	25	5	11	15	6.9	3.2	....
Sault Ste. Marie	614	11	61	29.38	30.11	+ .08	22.2	+ 0.9	48	30	30	− 6	2	14	27	19	16	80	1.42	− 0.4	8	7,420	nw.	32	nw.	25	10	7	14	6.1	1.8	T.
Chicago	823	140	310	29.19	30.10	+ .07	35.7	+ 1.3	65	15	42	10	2	29	28	32	26	68	1.87	− 0.7	14	8,930	nw.	43	sw.	25	6	9	16	6.4	1.5	....
Green Bay	617	109	144	29.39	30.08	+ .04	28.7	+ 1.9	59	14	36	5	1	21	23	25	21	76	0.87	− 1.5	9	9,760	ne.	48	sw.	25	5	13	13	6.7	2.1	....
Milwaukee	681	119	133	29.32	30.08	+ .05	32.0	+ 1.1	65	26	38	6	2	26	32	28	23	71	3.19	+ 0.5	12	8,270	n.	42	sw.	25	8	11	12	5.8	4.7	....
Duluth	1,133	11	47	28.86	30.13	+ .07	23.2	− 0.9	53	14	31	−12	1	16	27	20	16	77	1.56	0.0	8	10,199	ne.	47	w.	16	9	13	9	5.4	13.3	0.5
North Dakota.							**26.2**	**+ 5.2**										**78**	**0.99**	**0.0**										**6.2**		
Moorhead	940	8	57	29.12	30.18	+ .10	26.6	+ 5.2	60	13	35	−10	1	18	37	24	22	85	1.47	+ 0.3	10	7,007	nw.	36	nw.	15	15	6	10	4.6	14.6	T.
Bismarck	1,674	8	57	28.33	30.19	+ .13	27.6	+ 5.5	71	13	38	−10	27	18	41	24	19	75	1.23	+ 0.2	8	8,361	nw.	47	nw.	15	11	7	13	5.9	15.6	T.
Devils Lake	1,482	11	44	28.50	30.14	+ .09	23.0	+ 4.5	53	14	32	− 9	26	14	39	20	17	80	0.76	− 0.2	7	9,076	nw.	46	w.	15	4	12	15	6.7	5.3	....
Williston	1,872	40	47	28.09	30.14	+ .10	27.4	+ 5.8	65	14	37	−15	26	18	38	24	19	73	0.50	− 0.2	6	7,091	nw.	44	nw.	15	1	14	16	7.4	4.2	T.
Upper Mississippi Valley.							**36.8**	**+ 0.8**										**75**	**1.59**	**− 0.8**										**6.0**		
Minneapolis	918	10	208				30.6		55	14	37	− 6	1	24	25				0.98	− 0.7	11	9,297	nw.	36	nw.	17	6	15	10	6.0	2.9	....
St. Paul	837	201	236	29.17	30.11	+ .06	30.8	+ 2.6	58	14	38	− 5	1	23	25	27	21	72	0.93	− 0.7	12	9,430	n.	40	nw.	15	8	15	8	5.6	3.4	....
La Crosse	714	11	48	29.30	30.09	+ .05	32.8	+ 1.9	66	15	41	1	1	25	34	....	....	....	1.62	0.0	12	4,384	n.	24	sw.	25	5	9	17	5.7	2.2	....
Madison	974	70	78	29.02	30.11	+ .07	30.4	+ 0.3	63	15	37	2	1	23	31	27	23	76	1.15	− 1.1	10	8,039	n.	42	sw.	25	6	9	16	6.7	2.2	....
Charles City	1,015	10	49	29.00	30.11	+ .06	32.2	+ 3.8	65	15	41	− 2	1	24	34	28	24	82	1.01	− 0.9	8	5,707	nw.	26	nw.	25	8	14	9	5.7	4.8	....
Davenport	606	71	79	29.42	30.10	+ .07	36.4	+ 1.0	70	15	45	5	1	28	37	32	28	77	2.96	+ 0.8	11	6,084	e.	29	w.	17	7	11	13	6.3	1.3	....
Des Moines	861	84	97	29.16	30.10	+ .06	37.2	+ 1.5	73	15	46	6	1	29	35	32	27	71	1.18	− 0.5	9	6,551	n.	30	s.	24	6	12	13	6.5	2.0	....
Dubuque	698	81	96	29.34	30.12	+ .08	34.6	+ 1.4	70	15	42	4	1	27	39	31	26	76	1.74	− 0.5	10	5,319	nw.	27	nw.	15	5	14	12	6.7	0.9	....
Keokuk	614	64	78	29.42	30.11	+ .08	39.0	+ 1.1	73	26	47	8	1	31	32	34	29	72	1.97	− 0.4	11	6,157	nw.	38	nw.	17	10	10	11	5.3	T.	....
Cairo	356	87	93	29.72	30.12	+ .08	44.6	− 2.4	76	15	52	18	2	37	28	39	33	69	3.31	− 0.7	12	7,458	s.	38	nw.	1	7	6	18	6.6	3.5	....
Peoria	609	11	45	29.43	30.11	+ .08	36.8	− 0.2	72	26	45	8	1	28	35	33	30	81	1.60	− 1.4	11	5,902	s.	33	sw.	25	14	4	13	5.4	1.1	....
Springfield, Ill	644	10	91	29.40	30.10	+ .07	39.2	+ 0.1	69	15	47	9	1	32	28	35	32	78	1.01	− 2.1	15	6,676	s.	31	nw.	17	9	8	14	6.3	6.2	....
Hannibal	534	74	109	29.51	30.10	+ .08	40.6	− 1.0	76	26	49	10	1	32	37	....	....	....	1.58	− 1.2	14	7,309	sw.	38	s.	25	11	7	13	5.7	2.7	....
St. Louis	567	265	303	29.18	30.10	+ .07	43.5	0.0	80	15	52	16	1	36	33	38	33	70	1.25	− 2.2	12	9,637	nw.	41	s.	25	12	10	9	5.1	5.2	....
Missouri Valley.							**38.1**	**+ 2.0**										**69**	**1.86**	**− 0.1**										**5.4**		
Columbia, Mo	781	11	84	29.25	30.11	+ .08	41.6	+ 0.2	79	15	51	8	20	32	37	....	....	....	3.36	+ 0.3	12	6,948	n.	34	nw.	1	9	4	18	6.2	5.5	....
Kansas City	963	161	181	29.04	30.10	+ .08	43.2	+ 2.4	82	15	54	16	22	34	36	37	32	70	3.02	+ 0.2	10	9,888	n.	46	nw.	17	11	10	10	5.0	5.1	....
St. Joseph	967	11	49	29.04	30.10	......	40.6	......	78	15	50	10	20	31	34	35	29	70	4.69	......	8	7,450	nw.	35	nw.	17	12	6	13	5.2	6.4	....
Springfield, Mo	1,324	98	104	28.67	30.10	+ .08	44.0	+ 0.5	77	15	53	17	20	35	33	38	31	67	3.37	− 0.7	15	8,143	se.	36	s.	24	12	8	11	5.1	4.4	....
Iola	984	11	50	29.03	30.10	+ .09	45.4	+ 2.0	82	15	57	15	20	33	41	....	....	....	2.12	− 0.2	6	6,774	n.	37	s.	24	11	14	6	4.5	1.0	....
Topeka	983	85	101	......	......	......	43.0	+ 2.1	83	15	53	13	20	33	43	....	....	....	2.00	− 0.3	8	8,162	n.	40	s.	24	12	11	8	4.7	4.8	....
Lincoln	1,189	11	84	28.82	30.12	+ .10	37.2	+ 1.2	73	14	47	− 2	20	27	45	32	27	72	3.45	+ 2.1	9	9,068	n.	44	n.	28	10	14	7	5.0	8.8	....
Omaha	1,105	115	121	28.90	30.12	+ .08	37.4	+ 1.4	69	13	46	9	22	29	36	32	25	66	1.52	+ 0.1	8	7,737	n.	36	n.	17	10	9	12	5.7	1.8	....
Valentine	2,598	47	54	27.35	30.15	+ .12	33.6	+ 1.7	73	13	45	3	19	23	40	....	....	....	0.47	− 0.7	6	8,236	nw.	44	nw.	20	11	8	12	5.5	5.2	....
Sioux City	1,135	94	164	28.87	30.12	+ .07	34.6	+ 2.0	71	13	44	6	1	26	45	30	24	69	0.79	− 0.5	7	9,408	nw.	42	nw.	17	9	12	10	5.6	0.7	....
Huron	1,306	56	67	28.71	30.16	+ .10	31.2	+ 4.5	72	13	41	0	1	21	45	27	20	67	0.37	− 0.6	5	8,763	nw.	45	nw.	5	10	8	13	5.9	0.8	....
Pierre	1,572	70	75	28.46	30.18	+ .13	32.3	+ 2.8	73	13	40	5	21	24	42	28	22	69	0.79	− 0.5	5	8,527	nw.	46	nw.	20	13	8	10	5.5	7.7	....
Yankton	1,233	49	57	28.76	30.12	+ .07	33.8	+ 2.6	76	13	44	6	19	24	47	....	....	....	1.02	− 0.1	10	7,066	nw.	32	nw.	5	10	8	13	5.9	3.9	....

TABLE I.—*Climatological data for United States Weather Bureau stations, March, 1914*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level, feet.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure in inches: Station, reduced to mean of 24 hours.	Pressure in inches: Sea level, reduced to mean of 24 hours.	Pressure in inches: Departure from normal.	Temperature: Mean max. + mean min. ÷ 2.	Temperature: Departure from normal.	Temperature: Maximum.	Temperature: Date.	Temperature: Mean maximum.	Temperature: Minimum.	Temperature: Date.	Temperature: Mean minimum.	Temperature: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 or more.	Wind: Total movement, miles.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
Northern Slope.							**35.0**	**+ 4.2**										**64**	**0.68**	**− 0.5**										**5.5**		
Havre	2,505	11	44	27.42	30.12	+ .12	33.8	+ 6.5	64	14	45	− 1	26	23	43	29	24	73	0.17	− 0.3	4	6,695	sw.	40	n.	17	5	12	14	6.6	1.7	....
Helena	4,110	87	114	25.85	30.14	+ .13	35.2	+ 4.2	63	12	46	0	26	24	35	29	22	62	0.68	− 0.1	10	6,378	sw.	44	nw.	17	8	8	15	6.0	8.8	....
Kalispell	2,962	11	34	27.00	30.12	+ .13	35.4	+ 2.4	57	17	46	6	26	25	34	30	24	68	1.17	+ 0.1	11	3,666	sw.	26	n.	17	10	11	10	5.1	7.3	....
Miles City	2,371	26	48	27.56	30.18	+ .16	35.8	+ 7.2	68	14	46	− 2	26	25	39	31	26	74	0.45	− 0.3	8	5,049	n.	36	nw.	18	4	25	2	5.2	2.5	....
Rapid City	3,234	46	50	26.66	30.17	+ .16	35.1	+ 3.5	71	13	46	5	19	24	50	28	21	63	0.62	− 0.4	7	6,638	nw.	42	n.	18	9	6	16	6.4	3.6	T.
Cheyenne	6,088	58	64	24.00	30.10	+ .14	34.0	+ 1.0	60	13	45	1	21	23	36	28	20	62	0.72	− 0.2	10	11,941	nw.	62	w.	15	11	16	4	4.7	5.4	....
Lander	5,372	60	68	24.66	30.10	+ .11	36.6	+ 5.3	64	15	51	4	21	22	45	28	17	51	0.18	− 1.4	4	4,774	sw.	56	sw.	27	11	15	5	4.8	1.4	....
Sheridan	3,790	10	47	26.16	30.15	......	34.6	......	67	14	47	− 1	26	22	43	29	22	67	1.14	......	12	5,299	nw.	40	nw.	19	6	12	13	5.9	8.9	....
Yellowstone Park	6,200	11	48	23.90	30.16	+ .14	30.5	+ 4.5	53	17	41	0	21	20	45	25	17	59	0.77	− 1.4	7	6,986	s.	31	nw.	18	10	12	9	5.0	6.9	....
North Platte	2,821	11	51	27.15	30.15	+ .15	38.3	+ 3.0	72	13	51	12	19	26	46	31	23	64	0.41	− 0.5	3	6,161	n.	32	nw.	18	12	12	7	5.0	T.	....
Middle Slope.							**43.8**	**+ 1.3**										**50**	**1.05**	**− 0.4**										**4.4**		
Denver	5,291	129	172	24.74	30.08	+ .13	40.4	+ 1.7	74	13	53	2	21	28	40	32	21	53	2.02	+ 1.0	10	6,212	sw.	46	ne.	18	12	10	9	5.0	11.1	....
Pueblo	4,685	80	86	25.31	30.07	+ .15	41.2	+ 0.6	72	15	56	9	6	26	49	31	20	52	0.32	− 0.5	6	4,642	nw.	43	nw.	24	12	14	5	4.3	3.6	....
Concordia	1,398	42	50	28.61	30.12	+ .11	41.3	+ 0.6	77	15	53	12	20	30	47	35	28	68	1.05	− 0.4	6	5,919	n.	31	s.	24	8	9	14	6.3	0.5	....
Dodge City	2,509	11	51	27.44	30.09	+ .12	43.7	+ 2.0	80	28	59	12	19	28	49	34	25	58	0.09	− 0.8	4	9,122	nw.	44	nw.	18	14	14	3	3.7	0.6	....
Wichita	1,358	139	158	28.60	30.06	+ .07	46.2	+ 2.1	81	15	58	14	20	35	42	38	29	57	1.13	− 1.1	7	10,353	s.	48	s.	24	23	7	1	2.6	0.5	....
Oklahoma	1,214	10	47	28.78	30.08	+ .10	50.0	+ 0.8	81	15	62	19	20	38	40	42	35	65	1.68	− 0.7	7	12,583	s.	54	s.	28	14	5	12	4.4	1.0	....
Southern Slope.							**53.0**	**− 0.2**										**50**	**0.39**	**− 0.6**										**3.8**		
Abilene	1,738	10	52	28.26	30.08	+ .12	55.2	+ 0.3	84	26	68	23	20	42	38	44	32	50	0.66	− 0.7	8	9,294	s.	38	sw.	24	15	6	10	4.5	0.1	....
Amarillo	3,676	10	49	26.29	30.06	+ .11	47.3	+ 2.3	82	15	63	14	20	31	47	37	28	57	0.15	− 0.5	3	7,349	sw.	37	w.	24	22	8	1	3.3	1.4	....
Del Rio	944	8	57	29.10	30.09	+ .14	60.4	− 1.3	91	31	73	28	13	48	43	....	....	....	0.62	− 1.1	3	6,546	se.	35	nw.	5	12	14	5	4.0	....	....
Roswell	3,566	75	85	26.41	30.05	+ .15	49.1	− 2.2	79	15	66	18	22	32	51	38	22	43	0.14	− 0.3	2	7,270	s.	46	ne.	18	19	7	5	3.2	0.6	....
Southern Plateau.							**52.4**	**+ 1.4**										**47**	**0.51**	**0.0**										**2.4**		
El Paso	3,762	110	133	26.22	30.00	+ .12	53.1	− 2.8	81	17	67	27	20	40	38	39	22	36	0.10	− 0.3	3	8,889	w.	48	ne.	19	21	6	4	2.7	0.7	....
Santa Fe	7,013	57	62	23.24	30.02	+ .13	39.4	0.0	63	17	52	14	22	27	37	30	19	49	0.82	+ 0.1	7	5,776	n.	28	nw.	24	15	12	4	3.5	7.0	....
Flagstaff	6,908	8	57	......	......	......	39.0	+ 3.1	65	18	52	16	22	26	41	....	....	....	0.26	......	3	......	e	34	sw.	23	16	11	4	....	2.6	....
Phoenix	1,108	76	81	28.80	29.95	+ .04	63.6	+ 3.1	90	17	77	41	4	50	39	49	34	39	0.92	+ 0.4	2	4,491	e.	28	w.	2	22	4	5	3.0	....	....
Yuma	141	9	58	29.80	29.95	+ .01	68.0	+ 3.5	96	16	83	42	5	53	46	53	38	42	0.72	+ 0.4	1	4,579	n.	35	n.	2	28	3	0	0.9	....	....
Independence	3,910	11	42	26.06	30.07	+ .13	51.2	+ 1.6	78	17	66	26	30	36	37	44	38	67	0.00	− 0.5	0	3,917	n.	....	....	....	27	4	0	1.7	....	....
Middle Plateau.							**43.7**	**+ 3.4**										**50**	**0.37**	**− 0.9**										**2.9**		
Reno	4,532	74	81	25.52	30.07	+ .09	46.8	+ 5.8	74	17	62	23	2	32	43	36	25	48	T.	− 1.2	0	4,999	w.	34	w.	1	23	7	1	2.3	T.	....
Tonopah	6,090	12	20	24.10	30.01	......	46.4	......	65	17	56	22	2	37	27	36	23	42	0.00	− 1.4	0	6,462	se.	41	nw.	1	23	6	2	2.3	....	....
Winnemucca	4,344	18	56	25.68	30.10	+ .09	44.6	+ 5.0	74	17	61	22	2	28	47	35	24	53	0.08	− 0.9	4	4,912	ne.	33	sw.	29	20	4	7	3.2	0.1	....
Modena	5,479	10	43	24.66	30.04	+ .08	41.8	+ 2.6	68	15	57	18	22	26	46	32	18	46	0.15	− 1.2	3	8,296	sw.	51	s.	23	20	7	4	3.0	T.	....
Salt Lake City	4,360	147	189	25.68	30.09	+ .11	45.0	+ 3.6	63	14	54	29	3	36	30	38	29	55	1.24	− 0.8	9	5,810	nw.	37	sw.	23	18	5	8	3.5	1.5	....
Durango	6,546	18	56	23.65	30.02	+ .10	40.0	+ 2.5	67	17	54	16	22	25	41	31	22	53	0.63	− 0.8	3	4,184	nw.	28	n.	5	18	11	2	2.6	6.3	....
Grand Junction	4,602	43	51	25.43	30.04	+ .10	44.2	+ 0.7	67	15	56	20	21	32	33	36	27	54	0.46	− 0.2	6	5,439	se.	35	sw.	23	16	11	4	3.5	T.	....
Northern Plateau.							**44.9**	**+ 4.6**										**58**	**0.56**	**− 1.0**										**5.8**		
Baker	3,471	48	53	26.52	30.15	+ .12	42.0	+ 6.5	62	17	53	22	25	31	30	35	27	57	0.33	− 1.1	5	5,153	s.	26	s.	30	12	12	7	4.3	0.5	....
Boise	2,739	78	86	27.26	30.15	+ .12	46.0	+ 3.8	66	14	56	30	25	36	33	38	28	53	0.39	− 1.0	4	4,017	se.	24	se.	29	7	10	14	6.3	1.2	....
Lewiston	757	40	48	29.30	30.12	+ .09	49.1	+ 5.1	69	22	60	29	10	38	33	....	....	....	0.37	− 0.9	9	2,881	e.	21	w.	22	6	11	14	6.6	....	....
Pocatello	4,477	46	54	25.55	30.13	+ .12	39.4	+ 2.5	62	14	50	19	19	29	33	33	26	61	1.02	− 0.7	6	6,086	se.	33	sw.	1	11	11	9	4.9	6.8	....
Spokane	1,929	101	110	28.03	30.12	+ .11	43.5	+ 4.6	65	12	53	26	26	34	30	37	30	61	0.65	− 0.9	11	5,418	sw.	36	sw.	14	8	6	17	6.7	1.2	....
Walla Walla	1,000	107	115	29.04	30.12	+ .10	49.4	+ 5.4	67	17	58	33	10	40	27	42	34	58	0.59	− 1.3	9	4,009	s.	24	sw.	1	7	12	12	6.3	....	....
North Pacific Coast Region.							**47.8**	**+ 3.6**										**81**	**2.66**	**− 2.3**										**6.9**		
North Head	211	11	56	29.88	30.12	+ .11	47.7	+ 2.8	72	20	52	35	31	44	23	46	44	86	3.86	− 1.4	19	11,902	se.	62	se.	29	6	7	18	7.0	0.1	....
Port Crescent	259	8	53	29.82	30.10	+ .12	43.1	+ 2.6	64	19	51	29	31	36	25	....	....	....	2.16	− 1.8	14	4,117	se.	22	s.	1	3	13	15	7.1	T.	....
Seattle	125	215	250	29.99	30.12	+ .13	47.6	+ 3.4	71	20	54	33	27	42	24	44	40	78	1.40	− 2.2	15	7,475	s.	45	sw.	30	5	9	17	7.2	T.	....
Tacoma	213	113	120	29.89	30.12	+ .12	47.2	+ 3.0	70	20	54	33	31	40	30	45	42	84	2.27	− 1.7	14	5,202	sw.	28	sw.	30	2	12	17	7.4	1.0	....
Tatoosh Island	86	7	57	29.96	30.06	+ .10	46.2	+ 3.3	66	20	50	32	26	42	17	44	42	88	4.89	− 3.7	21	13,702	e.	65	sw.	1	3	11	17	7.4	0.2	....
Portland, Oreg.	153	68	106	29.95	30.11	+ .09	51.1	+ 4.8	71	18	58	38	3	44	24	46	41	71	2.28	− 2.9	17	5,408	sw.	27	w.	24	6	9	16	6.6	....	....
Roseburg	510	9	57	29.56	30.12	+ .08	51.8	+ 5.2	79	20	61	30	25	42	38	47	43	77	1.76	− 2.2	11	2,178	s.	21	s.	28	3	23	5	5.3	....	....
Middle Pacific Coast Region.							**55.7**	**+ 4.4**										**69**	**1.28**	**− 2.9**										**3.9**		
Eureka	62	73	89	30.07	30.14	+ .08	49.3	+ 1.3	78	19	55	35	29	44	29	47	45	86	3.13	− 3.8	9	5,075	n.	31	n.	23	8	7	16	6.5	....	....
Mount Tamalpais	2,375	11	18	27.60	30.08	+ .02	53.2	+ 6.1	77	17	59	34	29	48	19	46	40	68	1.49	− 3.7	5	10,910	sw.	62	nw.	1	18	8	5	3.4	T.	....
Point Reyes Light	490	7	18	29.52	30.04	......	54.6	+ 5.0	88	17	60	43	29	50	36	....	....	....	0.40	......	4	14,450	nw.	68	s.	28	10	11	10	5.3	....	....
Red Bluff	332	50	56	29.70	30.06	+ .02	59.8	+ 6.0	91	17	71	40	3	49	40	50	41	57	0.50	− 3.3	2	4,612	s.	24	s.	28	19	5	7	3.1	....	....
Sacramento	69	106	117	29.99	30.06	+ .03	58.1	+ 3.9	82	17	67	39	27	49	27	52	45	66	0.59	− 2.4	2	5,662	s.	29	se.	29	22	6	3	2.4	....	....
San Francisco	155	200	204	29.90	30.07	+ .01	58.4	+ 5.7	86	18	65	43	29	52	28	52	46	68	1.09	− 2.0	4	4,951	w.	29	s.	29	18	11	2	3.3	....	....
San Jose	141	12	110	29.92	30.07	......	56.8	+ 3.1	88	17	69	34	27	45	39	....	....	....	0.90	− 2.1	4	3,999	nw.	30	se.	29	18	6	7	3.2	....	....
South Pacific Coast Region.							**60.4**	**+ 5.3**										**66**	**0.61**	**− 2.0**										**3.5**		
Fresno	327	89	98	29.71	30.06	+ .05	58.9	+ 4.0	83	19	71	35	30	47	32	53	48	70	0.25	− 1.5	1	4,183	nw.	32	nw.	1	17	11	3	3.4	....	....
Los Angeles	338	159	191	29.66	30.02	00	63.0	+ 7.4	94	17	73	44	30	53	41	53	45	61	0.58	− 2.4	3	4,189	ne.	22	se.	29	19	7	5	3.4	....	....
San Diego	87	62	70	29.91	30.00	− .02	61.4	+ 5.2	88	7	69	48	16	54	33	54	48	68	0.36	− 1.3	4	4,465	nw.	27	se.	18	20	8	3	3.1	....	....
San Luis Obispo	201	47	54	29.85	30.07	+ .01	58.8	+ 4.7	93	18	69	32	30	48	43	51	45	66	1.24	− 2.7	2	3,850	nw.	22	se.	29	16	6	9	4.2	....	....
West Indies.																																
San Juan	82	8	54	29.93	30.02	.00	75.6	......	87	16	81	65	1	70	19	....	....	....	4.14	+ 1.0	16	8,750	se.	32	e.	22	12	15	4	4.3	....	....
Panama.																																
Ancon	92	6	69	29.76	29.85	......	82.9	......	96	26	94	68	2	72	24	73	70	76	T.	− 0.7	0	8,801	nw.	27	nw.	14	9	22	0	4.4	....	....
Culebra	404	5	62	29.46	29.88	......	80.2	......	92	3	89	69	4	72	22	72	70	80	0.01	− 0.6	1	8,776	nw.	31	n.	25	9	20	2	4.5	....	....
Colon	10	5	71	29.87	29.90	......	81.3	......	87	21	85	72	5	77	14	75	73	80	0.91	− 0.7	13	12,779	n.	35	ne.	10	15	14	2	4.2	....	....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1914, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	26			0.22														.11			
Albany, N. Y.	30			0.45														.15			
Alpena, Mich.	29			0.50														(*)			
Amarillo, Tex.	21			0.09														(*)			
Anniston, Ala.	30			1.24														.39			
Asheville, N. C.	30			0.36														.34			
Atlanta, Ga.	31	6.35 a. m.	10.10 a. m.	0.77	8.55 a. m.	9.24 a. m.	.13	.07	.21	.37	.48	.57	.61								
Atlantic City, N. J.	18			0.28														.18			
Augusta, Ga.	12			0.60														.28			
Baker, Oreg.	1			0.19														.08			
Baltimore, Md.	5-6			0.39														(*)			
Bentonville, Ark.	29			1.04														.59			
Binghamton, N. Y.	27			0.61														.45			
Birmingham, Ala.	30-31	1.34 p. m.	6.20 a. m.	3.07	2.10 p. m.	2.27 p. m.	.12	.11	.32	.59	.63										
Bismarck, N. Dak.	24			0.75														(*)			
Block Island, R. I.	1			1.34														.16			
Boise, Idaho.	4			0.14														.06			
Boston, Mass.	27			0.33														.31			
Buffalo, N. Y.	30			0.40														.18			
Burlington, Vt.	1			0.54														(*)			
Cairo, Ill.	29			0.87														.46			
Canton, N. Y.	1-2			1.02														(*)			
Charles City, Iowa.	28-29			0.49														(*)			
Charleston, S. C.	5			0.53														.28			
Charlotte, N. C.	11			0.29														.15			
Chattanooga, Tenn.	30			0.89														.58			
Cheyenne, Wyo.	4-5			0.31														(*)			
Chicago, Ill.	26-27			0.81														(*)			
Cincinnati, Ohio.	27			1.38														.23			
Cleveland, Ohio.	30			0.46														.22			
Columbia, Mo.	31	5.47 p. m.	[1]7.30 a. m.	1.98	7.34 p. m.	8.27 p. m.	.07	.21	.45	.70	1.01	1.15	1.24	1.29	1.32	1.37	1.43	1.48			
Columbia, S. C.	12			0.93														.24			
Columbus, Ohio.	29			0.15														.14			
Concord, N. H.	1			2.24														(*)			
Concordia, Kans.	30			0.74														.33			
Corpus Christi, Tex.	11	6.18 a. m.	8.55 a. m.	0.87	7.35 a. m.	7.59 a. m.	.14	.06	.24	.49	.59	.64									
Dallas, Tex.	30	10.52 a. m.	3.26 p. m.	2.16	1.19 p. m.	2.44 p. m.	.10	.33	.46	.56	.61	.70	.72	.72	.73	.76	.80	1.16	1.95	2.05	
Do.	31	7.12 a. m.	3.15 p. m.	0.62	12.33 p. m.	12.51 p. m.	.03	.10	.30	.46	.52										
Davenport, Iowa.	28-29	7.18 p. m.	5.00 a. m.	1.39	8.13 p. m.	8.33 p. m.	.08	.32	.56	.66	.75										
Dayton, Ohio.	27			1.31														.22			
Del Rio, Tex.	11			0.30														.28			
Denver, Colo.	18-19			0.81														(*)			
Des Moines, Iowa.	28			0.49														.31			
Detroit, Mich.	27			0.91														.17			
Devils Lake, N. Dak.	31			0.37														(*)			
Dodge City, Kans.	5			0.04														(*)			
Dubuque, Iowa.	28			0.45														.23			
Duluth, Minn.	4-5			0.56														(*)			
Durango, Colo.	30			0.40†														(*)			
Eastport, Me.	18			0.61														.18			
Elkins, W. Va.	17-18			0.46														(*)			
El Paso, Tex.	20			0.05														(*)			
Erie, Pa.	27-28			1.52														(*)			
Escanaba, Mich.	28-29			0.79														(*)			
Eureka, Cal.	28			2.26														.32			
Evansville, Ind.	27			1.38														.33			
Flagstaff, Ariz.	30			0.17														(*)			
Fort Smith, Ark.	18-19			0.72														.20			
Fort Wayne, Ind.	26			0.74														.47			
Fort Worth, Tex.	30	11.53 a. m.	2.32 p. m.	1.73	1.14 p. m.	1.49 p. m.	.27	.06	.19	.42	.76	1.04	1.21	1.32							
Fresno, Cal.	29			0.25														.13			
Galveston, Tex.	26-27	1.20 p. m.	D. N. a. m.	2.85	4.45 p. m.	5.35 p. m.	.12	.11	.17	.28	.59	.70	.70	.71	.74	.86	.95				
					5.35 p. m.	6.25 p. m.		1.03	1.10	1.17	1.28	1.36	1.40	1.48	1.64	1.79	1.83				
					6.25 p. m.	7.02 p. m.		1.87	1.91	1.95	2.04	2.19	2.38	2.49	2.52						
Grand Haven, Mich.	26-27			0.67														(*)			
Grand Junction, Colo.	23			0.11														.08			
Grand Rapids, Mich.	27			0.52														.26			
Green Bay, Wis.	29			0.45														(*)			
Hannibal, Mo.	31			0.45														.26			
Harrisburg, Pa.	6-7			0.70														(*)			
Hartford, Conn.	1			2.08														.41			
Hatteras, N. C.	20			0.59														.28			
Havre, Mont.	24-25			0.09														(*)			
Helena, Mont.	24-25			0.29														(*)			
Houghton, Mich.	25			0.24														(*)			
Houston, Tex.	3	6.42 p. m.	D. N. p. m.	0.95	9.50 p. m.	10.16 p. m.	.01	.27	.65	.77	.85	.91	.94								
	26	1.40 p. m.	D. N. p. m.	1.50	4.59 p. m.	5.24 p. m.	.92	.06	.12	.22	.42	.50									
Huron, S. Dak.	30-31			0.21														(*)			
Independence, Cal.				(‡)																	
Indianapolis, Ind.	27			1.33														.30			
Iola, Kans.	29			1.19														.48			
Jacksonville, Fla.	5			0.78														.37			
Kalispell, Mont.	25-26			0.59														(*)			
Kansas City, Mo.	28			0.98														.53			
Keokuk, Iowa.	28			1.30														(*)			
Key West, Fla.	5			0.25														.11			
Knoxville, Tenn.	19-20			1.01														(*)			
La Crosse, Wis.	29			0.70														.12			
Lander, Wyo.	20			0.06														(*)			
Lansing, Mich.	27			0.58														(*)			
Lewiston, Idaho.	30			0.08														.05			
Lexington, Ky.	10			0.54														.25			
Lincoln, Nebr.	28			1.74														.87			
Little Rock, Ark.	30			0.99														.45			
Los Angeles, Cal.	29			0.34														.12			
Louisville, Ky.	27			1.11														.28			
Ludington, Mich.	28-29			1.44														(*)			
Lynchburg, Va.	17-18			0.73														.18			
Macon, Ga.	11			0.53														.21			
Madison, Wis.	29			0.22														.15			

[1] April 1.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1914, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Marquette, Mich	29			0.47														(*)			
Memphis, Tenn	29			1.12														.48			
Meridian, Miss	11			1.06														.41			
Miami, Fla	14			0.72														.33			
Milwaukee, Wis	28-29	7.30 p. m.	2.30 p. m.	2.01	9.16 a. m.	10.48 a. m.	.60	.09	.18	.23	.27	.33	.47	.53	.57	.59	.61	.69	1.14	1.31	
Minneapolis, Minn	24-25			0.29														(*)			
Mobile, Ala	4			0.99														.37			
Modena, Utah	28			0.09														.04			
Montgomery, Ala	11			1.69														.61			
Moorhead, Minn	24-25			0.98														(*)			
Mount Tamalpais, Cal	29			0.90														.36			
Mount Weather, Va	5-6			0.54†														(*)			
Nantucket, Mass	1			1.05														.22			
Nashville, Tenn	29-30	11.38 a. m.	9.15 a. m.	2.17	5.49 a. m.	6.24 a. m.	.71	.19	.42	.58	.61	.63	.97	1.16							
New Haven, Conn	1	D. N. a. m.	4.30 p. m.	2.52	1.58 p. m.	3.09 p. m.	1.30	.05	.10	.15	.21	.26	.35	.44	.55	.65	.73	.85	1.07		
New Orleans, La	25			1.23														.47†			
New York, N. Y	1-2			2.99														.45†			
Norfolk, Va	30			0.33														.16			
Northfield, Vt	1			1.90														(*)			
North Head, Wash	31			0.58														.21			
North Platte, Nebr	30-31			0.32														(*)			
Oklahoma, Okla	24			0.37														.37			
Omaha, Nebr	28			0.89														.28			
Oswego, N. Y	27			0.90														(*)			
Palestine, Tex	10-11	7.35 p. m.	4.10 a. m.	1.64	10.19 p. m.	10.54 p. m.	.05	.20	.30	.38	.44	.49	.59	.64							
	30	2.15 p. m.	8.45 p. m.	1.04	5.14 p. m.	5.31 p. m.	.21	.15	.28	.52	.56										
	31	11.50 a. m.	5.10 p. m.	2.25	12.37 p. m.	1.24 p. m.	.03	.17	.19	.27	.51	.66	.70	.72	.75	1.02	1.13				
Parkersburg, W. Va	30			0.36														.20			
Pensacola, Fla	4			1.74														.66			
Peoria, Ill	26			0.64														.35			
Philadelphia, Pa	18			0.35														(*)			
Phoenix, Ariz	29			0.39														.30			
Pierre, S. Dak	18			0.44														(*)			
Pittsburgh, Pa	27-28			0.67														(*)			
Pocatello, Idaho	4			0.44														(*)			
Point Reyes Light, Cal	29			0.29														.11			
Port Huron, Mich	30			0.36														.16			
Portland, Me	1			1.87														.21			
Portland, Oreg	30			0.29														.11			
Providence, R. I	1			1.30														(*)			
Pueblo, Colo	5			0.22														(*)			
Raleigh, N. C	31			1.22														.48			
Rapid City, S. Dak	31			0.20														.20			
Reading, Pa	6			0.51†														(*)			
Red Bluff, Cal	29			0.49														.18			
Reno, Nev	1			T.														T.			
Richmond, Va	20			1.08														.15			
Rochester, N. Y	1-2			1.53														(*)			
Roseburg, Oreg	1			0.33														.12			
Roswell, N. Mex	21			0.10														(*)			
Sacramento, Cal	29			0.51														.15			
Saginaw, Mich	26			0.34														.11			
St. Joseph, Mo	28	4.26 p. m.	5.43 p. m.	0.72	4.42 p. m.	4.54 p. m.	.01	.31	.55	.59											
		6.37 p. m.	D. N. p. m.	2.15	7.22 p. m.	8.30 p. m.	.15	.09	.19	.43	.58	.60	.63	.68	.75	.80	.86	1.46	1.64		
St. Louis, Mo	10			0.31														(*)			
St. Paul, Minn	28-29			0.25														(*)			
Salt Lake City, Utah	1-2			0.74														(*)			
San Antonio, Tex	19			0.59														.24			
San Diego, Cal	28			0.13														.10			
Sand Key, Fla	22			0.27														.13			
Sandusky, Ohio	26			0.22														.21			
San Francisco, Cal	29			0.94														.41			
San Jose, Cal	29			0.83														.32			
San Luis Obispo, Cal	29			1.23														.40			
Santa Fe, N. Mex	30-31			0.41														(*)			
Sault Ste. Marie, Mich	29			0.71														(*)			
Savannah, Ga	21			0.53														.13			
Scranton, Pa	1-2			2.66														(*)			
Seattle, Wash	28			0.20														.12			
Sheridan, Wyo	18			0.30														(*)			
Shreveport, La	31	12.30 p. m.	1.25 p. m.	0.63	12.40 p. m.	1.00 p. m.	.01	.09	.29	.41	.50										
		2.10 p. m.	6.40 p. m.	2.03	4.15 p. m.	4.56 p. m.	.64	.26	.55	.71	.79	.83	.86	1.03	1.15	1.19					
Sioux City, Iowa	31			0.34														(*)			
Spokane, Wash	23			0.24														.12			
Springfield, Ill	26-27			0.26														(*)			
Springfield, Mo	24-25			1.39														(*)			
Syracuse, N. Y	1-2			1.59														(*)			
Tacoma, Wash	28			0.15														.13			
Tampa, Fla	5			0.75														.50			
Tatoosh Island, Wash	13			0.99														.18			
Taylor, Tex	10-11			0.87														.54			
Terre Haute, Ind	29			0.94														.45			
Thomasville, Ga	11-12			0.32														.15			
Toledo, Ohio	27			1.23														.25			
Tonopah, Nev				(‡)																	
Topeka, Kans	28			0.87														.40			
Valentine, Nebr	18			0.37														(*)			
Vicksburg, Miss	26	5.20 a. m.	D. N. p. m.	4.72	5.30 a. m.	6.11 a. m.	.02	.06	.22	.35	.40	.44	.48	.56	.62	.64					
					7.30 p. m.	7.59 p. m.	3.49	.05	.11	.18	.39	.58	.66								
	28	1.15 a. m.	D. N. a. m.	1.74	2.53 a. m.	3.45 a. m.	.15	.09	.24	.34	.40	.44	.56	.94	1.28	1.45	1.51	1.58			
	30-31	10.55 p. m.	2.40 p. m.	2.76	1.20 a. m.	2.11 a. m.	.16	.08	.12	.24	.30	.32	.36	.53	.61	.77	.94	.97			
Walla Walla, Wash	1			0.14														.06			
Washington, D. C	5-6			0.64†														(*)			
Wichita, Kans	29	1.00 a. m.	1.45 a. m.	0.65	1.08 a. m.	1.32 a. m.	.01	.14	.21	.39	.47	.63									
Williston, N. Dak	24-25			0.24														(*)			
Wilmington, N. C	20			0.39														.25			
Winnemucca, Nev	23			0.05														.05			
Wytheville, Va	10			0.25														.14			
Yankton, S. Dak	30			0.24														.18			
Yellowstone Park, Wyo	25			0.40														(*)			

* Self-register does not work in freezing weather. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, March, 1914.*

Stations.	Pressure.			Temperature.						Precipitation.		
	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Inches.	*Inches.*	*Inches.*	°F.	°F.	°F.	°F.	°F.	°F.	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F	29.68	29.82	−.06	30.4	+ 2.7	35.8	24.9	45	12	6.17	+1.41	9.0
Sydney, C. B. I	29.90	29.94	+.06	30.2	+ 4.0	36.1	24.3	50	14	4.02	−0.91	24.0
Halifax, N. S	29.85	29.96	+.02	31.4	+ 2.4	37.9	24.9	50	11	4.03	−1.43	4.9
Yarmouth, N. S	29.88	29.95	.00	32.6	+ 1.8	38.1	27.2	52	15	3.08	−1.77	6.8
Charlottetown, P. E. I	29.89	29.93	+.03	29.4	+ 4.0	34.7	24.1	46	10	2.79	−0.42	9.7
Chatham, N. B	29.95	29.97	+.07	28.4	+ 5.4	36.5	20.3	48	4	3.98	+0.51	22.3
Father Point, Que	29.93	29.95	−.02	25.7	+ 5.4	31.8	19.6	43	6	1.27	−1.46	12.1
Quebec, Que	29.64	29.98	+.02	25.6	+ 4.4	32.3	18.8	47	− 2	1.97	−1.29	18.5
Montreal, Que	29.77	29.99	−.01	27.3	+ 3.5	33.1	21.6	50	2	2.74	−1.05	23.0
Ottawa, Ont	29.74	30.08	+.07	25.6	+ 4.1	33.1	18.0	49	0	1.35	−1.37	13.2
Kingston, Ont	29.72	30.04	+.03	27.4	+ 1.8	34.7	20.0	50	0	1.37	−1.27	6.5
Toronto, Ont	29.61	30.01	−.01	30.7	+ 3.4	37.5	23.8	55	4	2.42	−0.22	11.8
White River, Ont	28.72	30.09	+.06	11.9	− 0.3	28.6	− 4.8	48	−38	0.90	−0.48	6.0
Port Stanley, Ont	29.39	30.05	+.02	30.4	+ 3.2	36.9	23.8	55	9	1.97	−0.91	4.9
Southampton, Ont	29.32	......	......	27.6	+ 2.9	35.2	19.9	55	4	1.89	−0.76	13.9
Parry Sound, Ont	29.32	30.05	+.03	24.5	+ 3.4	34.0	15.0	54	− 6	1.67	−0.56	10.4
Port Arthur, Ont	29.40	30.14	+.09	21.0	+ 4.2	32.0	10.0	48	−14	0.94	−0.03	8.2
Winnipeg, Man	29.30	30.17	+.08	20.7	+ 8.4	29.4	12.0	46	16	0.59	−0.44	5.8
Minnedosa, Man	28.27	30.16	+.10	20.1	+ 7.6	29.9	10.3	44	−20	0.39	−0.26	3.9
Qu'Appelle, Sask	27.76	30.09	+.05	22.2	+ 7.3	31.7	12.6	51	−16	1.05	+0.28	10.5
Medicine Hat, Alberta	27.72	30.04	+.04	34.7	+ 7.2	46.3	23.2	65	−10	0.59	−0.17	4.2
Swift Current, Sask	27.42	30.07	+.05	26.8	+ 4.8	37.7	15.8	61	− 9	0.79	−0.02	7.9
Calgary, Alberta	26.43	30.06	+.11	31.0	+ 4.8	43.1	18.9	67	−18	0.76	+0.04	7.6
Banff, Alberta	25.34	30.05	+.11	28.1	+ 7.9	38.3	17.9	51	−21	0.90	−0.51	8.1
Edmonton, Alberta	27.72	30.07	+.11	28.2	+ 4.0	37.3	19.0	57	−12	0.35	−0.37	3.2
Battleford, Sask	28.30	30.11	+.05	24.6	+11.5	33.8	15.4	50	−15	0.80	+0.34	8.0
Kamloops, B. C	28.82	30.12	+.20	39.9	+ 3.8	50.1	29.7	61	10	0.26	−0.31	T.
Victoria, B. C	29.98	30.08	+.11	46.9	+ 5.0	53.3	40.5	68	29	2.05	−1.07	0.1
Barkerville, B. C	25.62	30.00	+.12	26.0	− 0.1	33.9	18.2	46	−14	2.55	+0.66	25.5
Hamilton, Bermuda	29.93	30.10	+.02	61.4	− 0.8	66.9	55.9	71	47	5.20	+0.07	......

Chart I. Hydrographs of Several Principal Rivers, March, 1914.

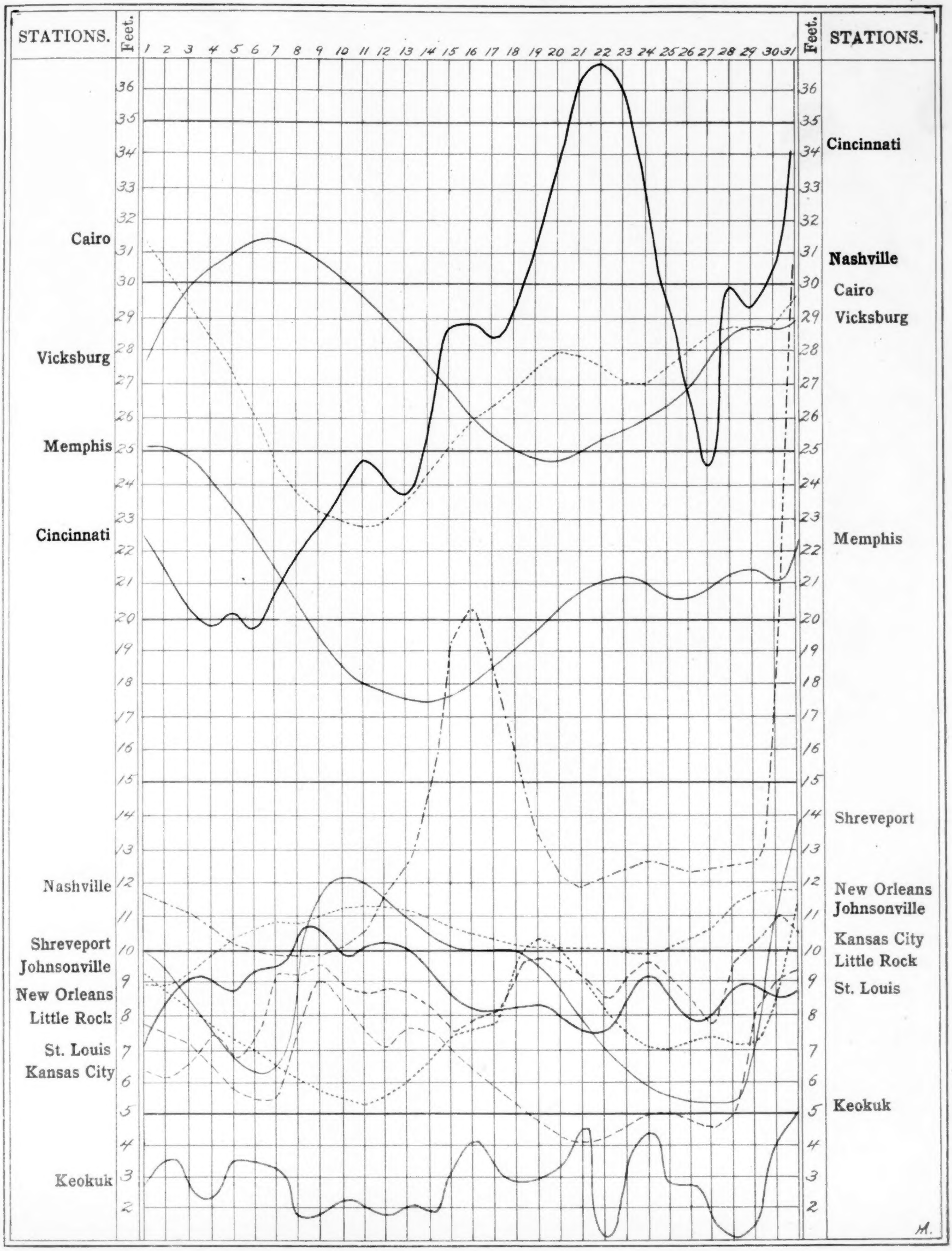

Chart II. Tracks of Centers of High Areas, March, 1914.

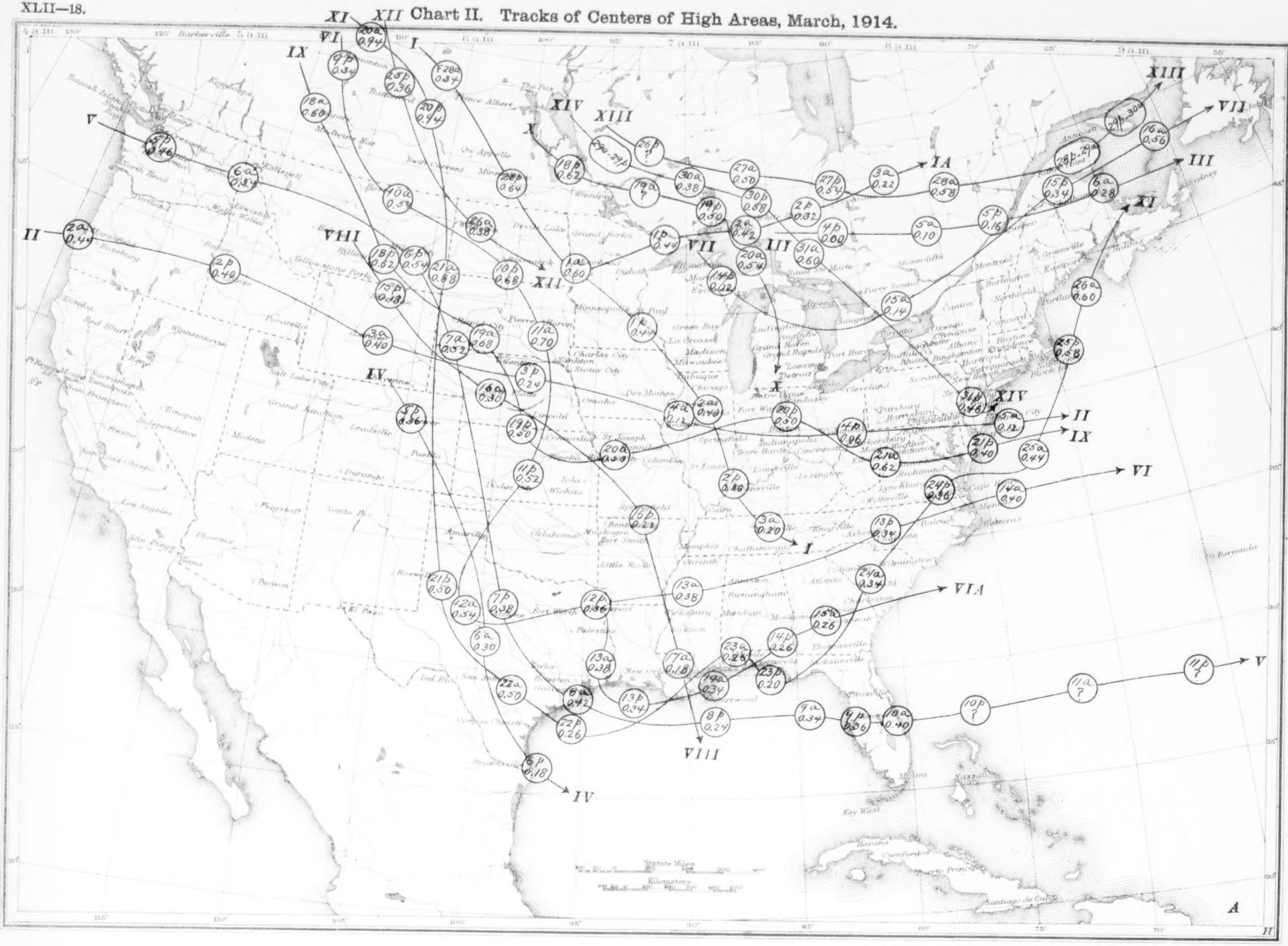

Chart III. Tracks of Centers of Low Areas, March, 1914.

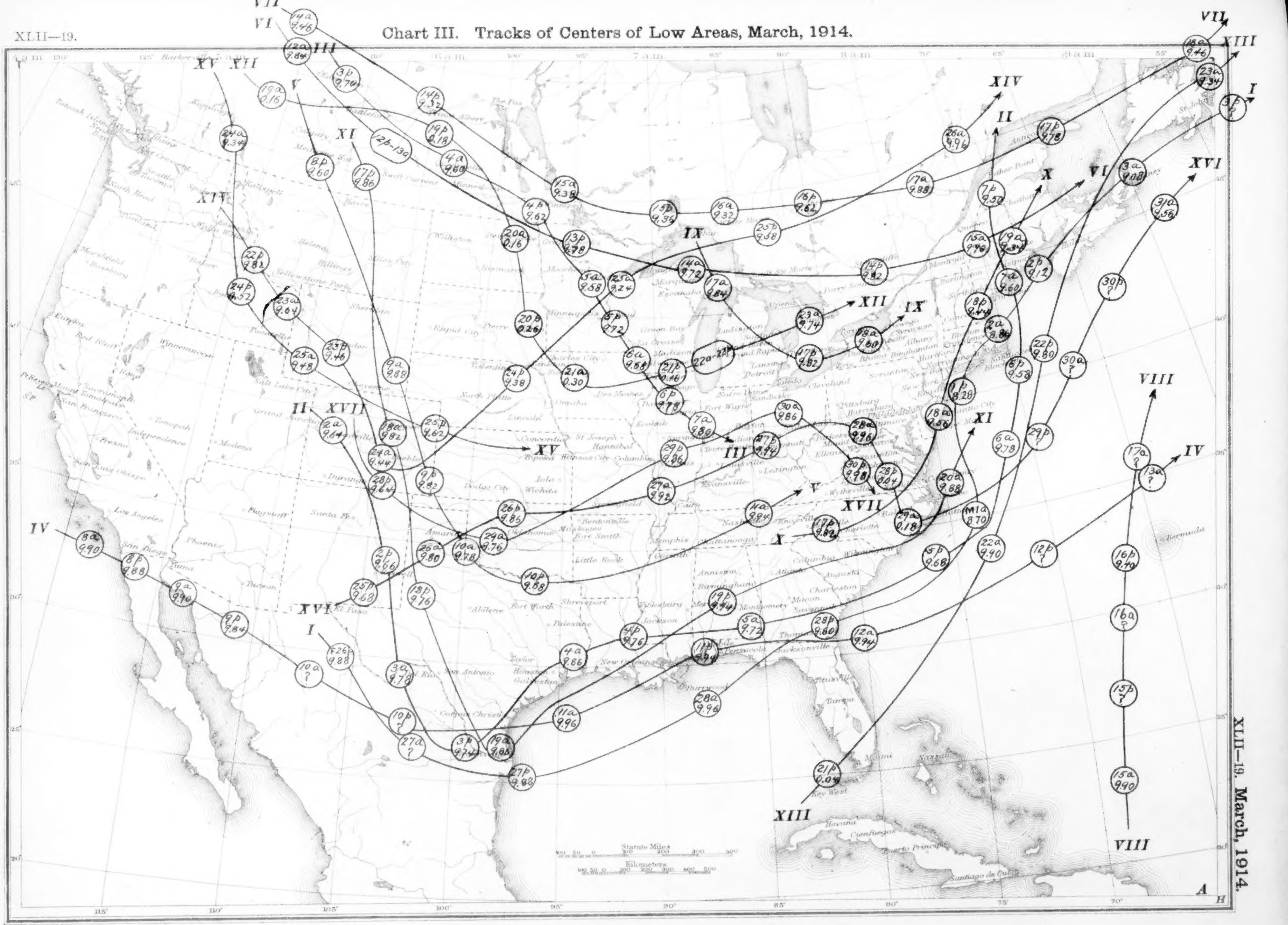

Chart IV. Departure of the Mean Temperature from the Normal, March, 1914.

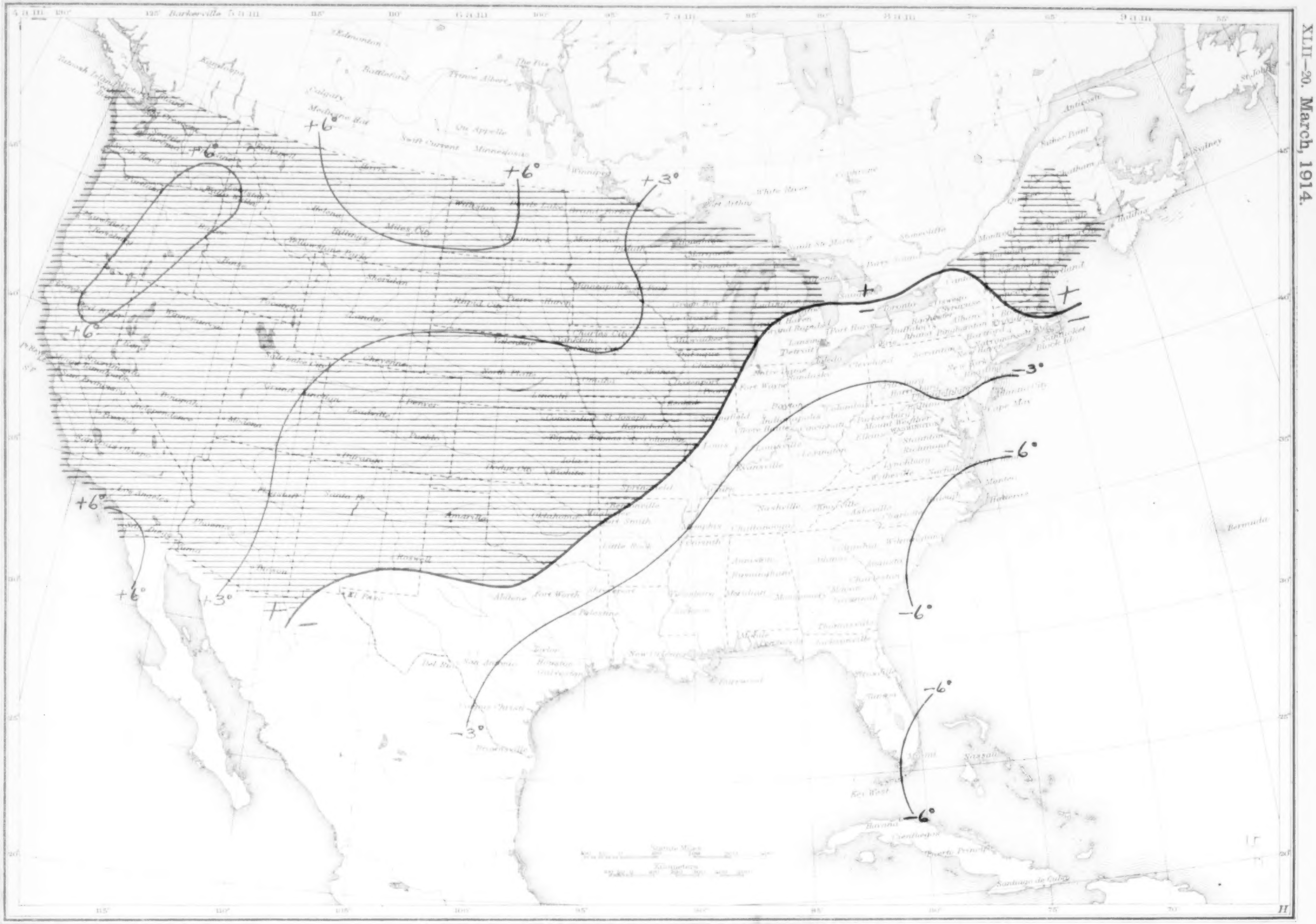

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Chart V. Total Precipitation, inches, March, 1914.

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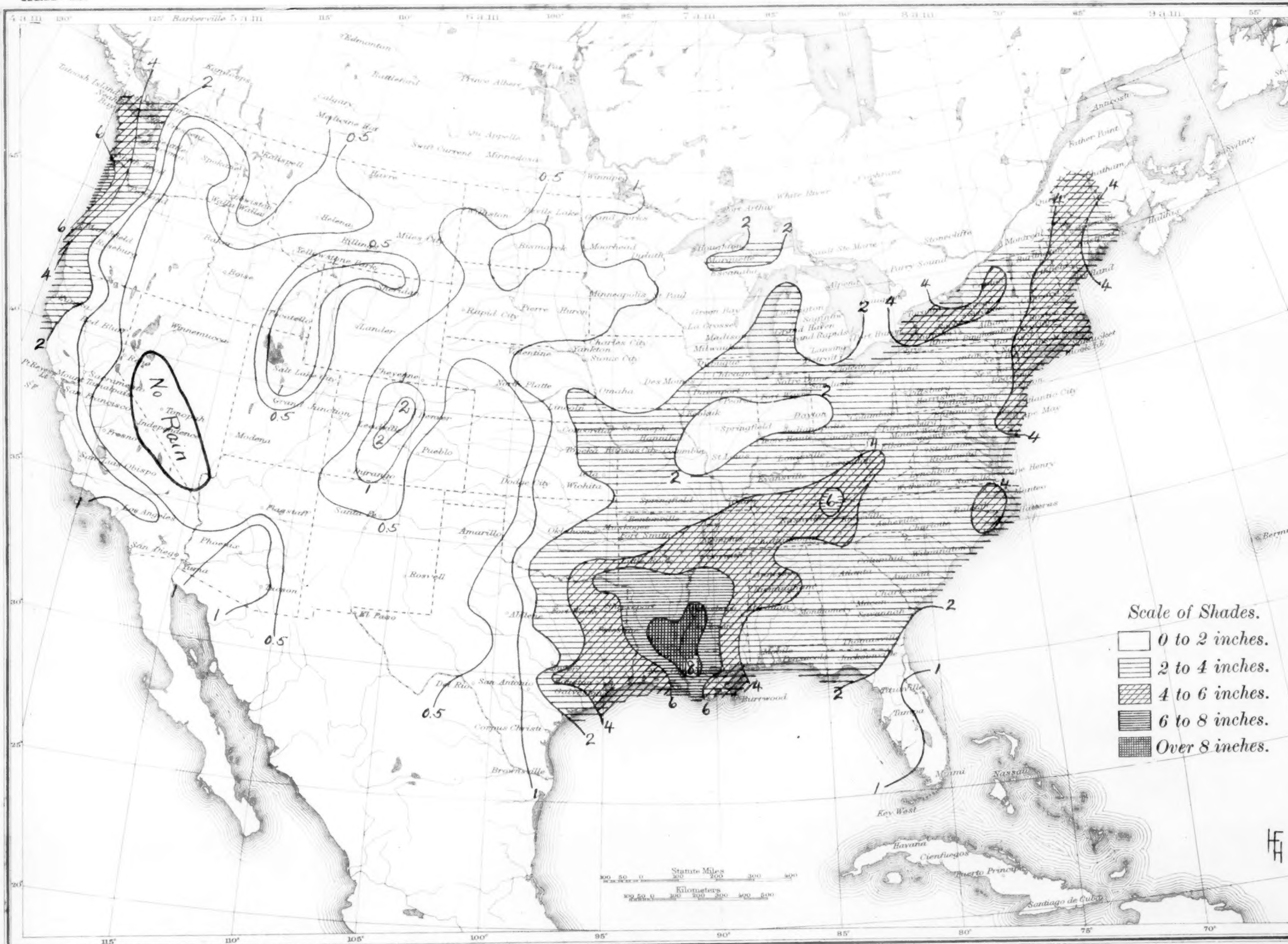

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, March, 1914.

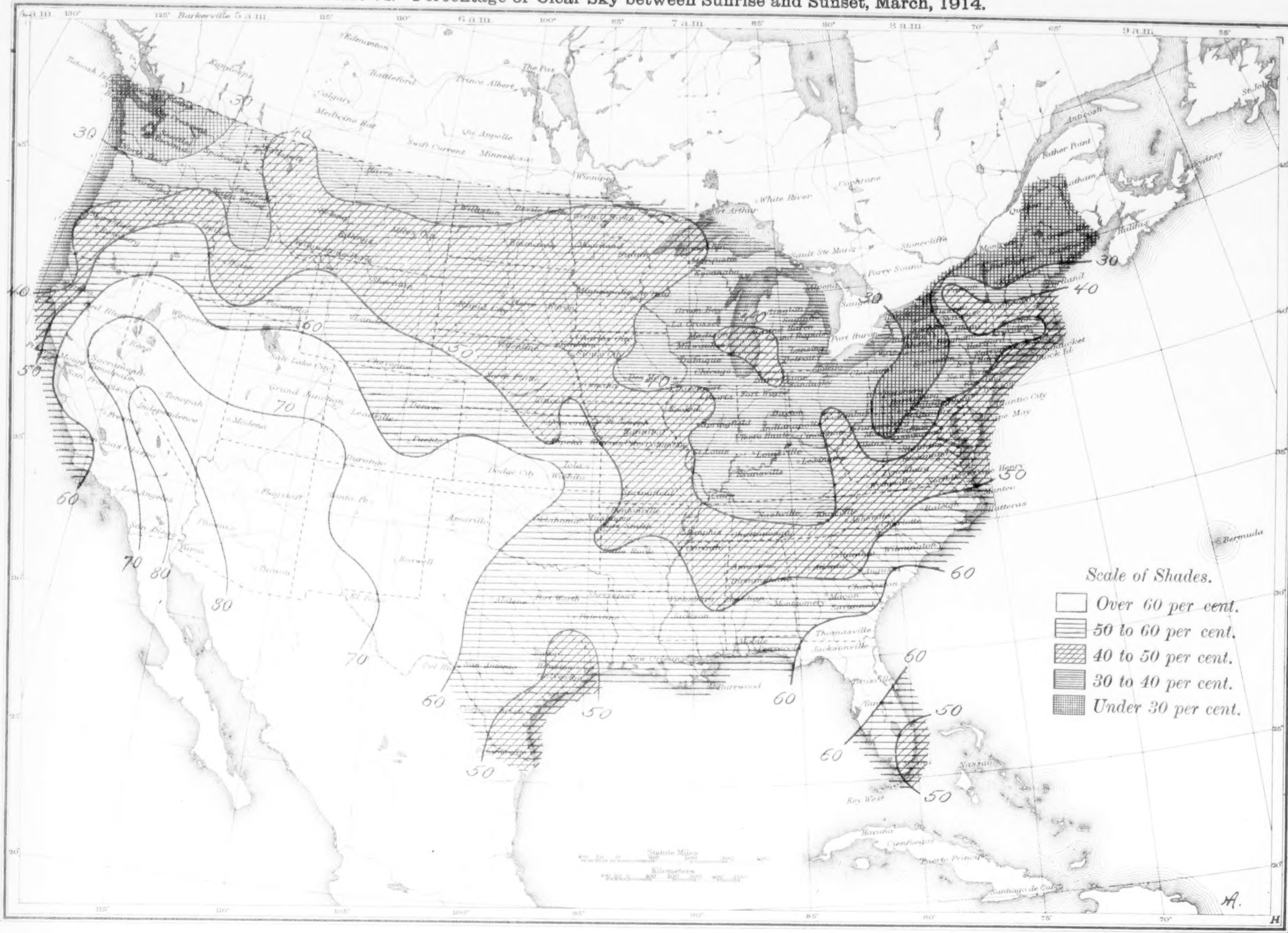

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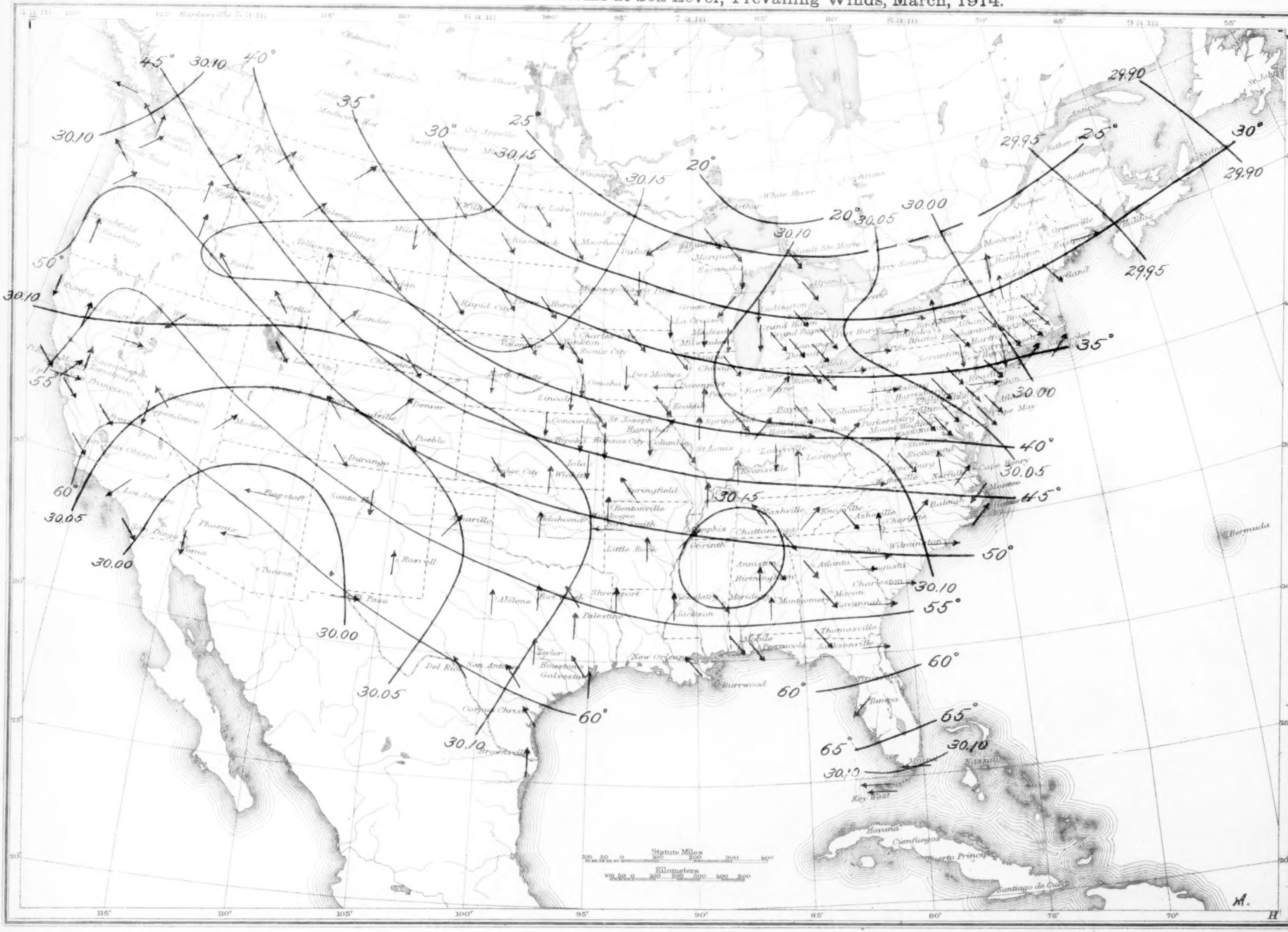
Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, March, 1914.

Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, March, 1914.



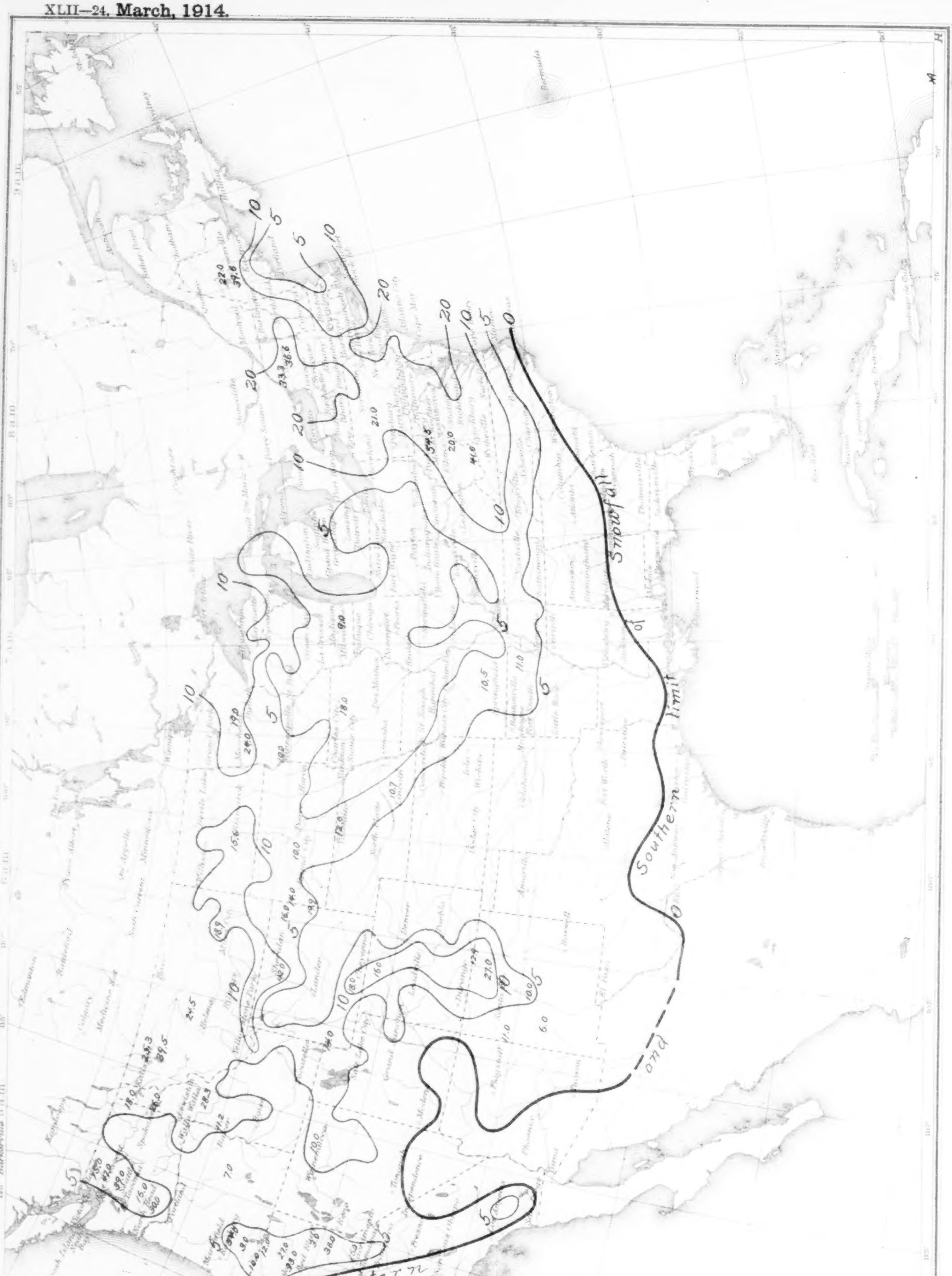


Chart VIII. Total Snowfall, inches, March, 1914.